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THE PROMOTION OF INNOVATION IN THE EU MARINE EQUIPMENT SECTOR

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THE PROMOTION OF INNOVATION IN THE EU MARINE EQUIPMENT SECTOR

by

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AUTHOR'S DECLARATION

At no time during the registration for the degree of *Doctor of Philosophy* has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee. Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

The following activities were undertaken in connection with the programme of the study:

- International Maritime Organisation Internship Programme, 2014, London, United Kingdom.
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ABSTRACT

MUHAMMAD NOOR AFFIQ BIN HASANUDDIN

The Promotion of Innovation in the EU Marine Equipment Sector.

Growing environmental regulation and calls for the maritime industry to go green are driving the demand to develop and apply green innovative technology on ships to deal with problems such as: ballast water pollution; carbon emissions; and emissions that affect air quality. The shipping industry must prepare for a future with lower external transport costs and therefore must embrace the challenges of implementing alternative measures to reduce its impact on the environment. The IMO and the EU are two institutions that are driving legislation to enforce this. Stricter environmental regulation has led to ship-owners exploring various solutions to comply such as adopting innovative emission abatement technology or using alternative fuels. Innovation in the marine equipment sector is needed to achieve this.

The drivers of innovation have been extensively studied but the globalised shipping industry is unique in the way it is impacted by multiple changes in the climate and interactions between people and places across the globe. This study is therefore concerned with discovering the variables that drive green innovation in the marine equipment sector within the European Union (EU).

The study aimed to gain a rich and complex understanding of green innovation in the EU ship equipment sector. It started with an explanatory synthesis of IMO and EU air pollution regulation. Questionnaires were then used to guide the formulation of interview questions for deep and rich data gathering.

The first questionnaire, aimed at ship-owners within the EU, was employed to identify solutions implemented to comply with stricter air regulations. The second set of questionnaires, aimed at equipment manufacturers in Europe, was employed to identify variables that encouraged or restrict green product innovation. Following that, semi-structured interviews were conducted with eight people who consisted of marine equipment manufacturers and academics, groups, organisations involved in the promotion of marine technological products.

The use of low sulphur fuel was found to be the most favourable solution for ship-owners to implement to comply with stricter air regulations. The use of technological products such as scrubbers, although not as significant, were also found to be implemented among several ship-owners. As the use of scrubbers indicates a demand for technological products, ship-owners were one of the drivers of innovation in equipment manufacturing companies. Other drivers of green product innovation also include: economic benefit; IMO and EU regulations; proof of concept; competition; profit maximisation and government schemes.

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LIST OF ABBREVIATIONS

ABS	American Bureau of Shipping
BC	Black Carbon
BWM Convention	Ballast Water Management Convention
CEO	Chief Executive Officer
CO2	Carbon Dioxide
CSR	Corporate Social Responsibility
DIUS	Department for Innovation, Universities and Skills
DNV-GL	Det Norske Veritas-Germanischer Lloyd
EBRD	European Bank for Reconstruction and Development
EC	European Commission
ECA	Emission Control Area
EEDI	Energy Efficiency Design Index
EEOI	Energy Efficiency Operational Indicator
EMEC	European Marine Equipment Council
EMP	Eco Marine Power
EMSA	European Maritime Safety Agency
EPA	Environmental Protection Agency
EU	European Union
GHG	Greenhouse Gas
HFO	Heavy Fuel Oil
ICS	International Chamber of Shipping
IEA	International Energy Agency
IMO	International Maritime Organisation
IOPPC	International Oil Pollution Protection Certificate
IPCC	Intergovernmental Panel on Climate Change

ITU	International Telecommunication Union
LNG	Liquefied Natural Gas
LSF	Low Sulphur Fuel
MARPOL	International Convention for the Prevention of Pollution from ships
MEPC	Marine Environment Protection Committee
MGO	Marine Gas Oil
MRV	Monitoring, Reporting and Verification
NOx	Nitrogen Oxides
OECD	Organisation for Economic Co-operation and Development
PM	Particulate Matter
SEA Europe	Shipyards' and Maritime Equipment Association (Europe)
SECA	Sulphur Emission Control Area
SEEMP	Ship Energy Efficiency Management Plan
SME	Small and Medium-Sized Enterprise
SOx	Sulphur Oxides
UK	United Kingdom
ULSFO	Ultra-Low Sulphur Fuel Oil
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNECE	United Nations Economic Commission for Europe
USD	United States Dollar

CHAPTER 1 INTRODUCTION

1.1 Research problem

This study is concerned with discovering the variables that drive green innovation in the marine equipment sector within the European Union (EU), with the aim of applying this knowledge within the European institutional framework for cleaner air. The institutional framework here refers to the EU and the International Maritime Organisation (IMO) systems of regulation.

1.2 Background

The global shipping industry plays a central role in international trade and the world economy (United Nations Conference on Trade and Development [UNCTAD], 2011). Despite these significant positive contributions, shipping activities have some adverse impacts on society and the global environment. The external costs of shipping activities include, among other things, air pollution, water pollution, oily discharge, garbage disposal and the discharge of biological contaminants present in ballast water.

There is a growing awareness of the environmental impacts caused by shipping (Notteboom *et al.*, 2010). The release of air pollutants, such as greenhouse gases and a range of noxious gases and particulate matter into the atmosphere, impact both human health and climate change (Omer, 2008). Another example is the presence of invasive aquatic species in ships' ballast water, such as bacteria, plants and animals. These present serious threats to human health and marine and coastal ecosystem (Rahman, 2017). As a result, a number of international maritime regulations have been issued to reduce harmful emissions and to prevent the spread of potentially harmful aquatic organisms in ships' ballast water, and to improve the overall environmental performance of new and existing ships (Hughes, 2011).

The focus of this research is air pollution which is defined by the United Nations Economic Commission for Europe [UNECE] (1979) as

> *"The introduction by [humans], directly or indirectly, of substances or energy into the air, resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and material property, and impair or interfere with amenities and other legitimate uses of the environment"* (p.2)

Air emissions from ships separate into two categories: those that impact climate change; and those that affect air quality, i.e. direct or indirectly affect human health and the health of the ecosystem (Tay, 2011). The source of air emissions from ships can be divided into air emissions from marine engines, cargo-related emissions and equipment related emissions. However, the focus of this research is on those air emissions from the marine engines of ships that affect air quality. The driver for this research is the stricter air emission regulation that is coming into force on 1 January 2020. This regulation, MARPOL Annex VI, sets global limits on the emissions of sulphur oxides (SOx), nitrogen oxides (NOx) and particulate matter (PM) from ship's exhaust (International Maritime Organisation [IMO], 2013b).

The effects of SOx on human health are to cause chest pains, breathing problems and eye irritation, and to lower resistance to heart and lung diseases (European Commission [EC], 2016b). SOx emissions also cause acid rain which leads to the acidification of ground and surface water, deforestation, death of aquatic life and decay of buildings. NOx also increases the likelihood of respiratory problems in humans (EMSA, 2017a). It inflames the lining of the lungs and can lead to reduced immunity to lung infections. This then causes problems such as wheezing, coughing, colds, influenza and bronchitis. NOx has adverse effects on the ecosystem where it can make vegetation more susceptible to disease and forest damage (Tay, 2011). As for PM, its effects on humans have been linked to increased asthma attacks, heart and lung disease and respiratory problems in susceptible population groups (World Health Organisation, 2013). The particles can also be carried over long distances by wind and then settle on ground or water. This causes environmental damage as the particles deplete the nutrients in the soil, damage sensitive forests and farm crops and change the nutrient balance in coastal waters (Tay, 2011).

Marine diesel engines burn low-quality bunker fuel, and it is this combustion that leads to emissions of SOx, NOx and PM from ships' exhausts. Bunker fuel, or Heavy Fuel Oil (HFO), is the fuel that the vast majority of international shipping burns. It is made up of a complex blend of hydrocarbons derived from various refinery streams (usually residues from crude oil refining processes). During combustion of HFO, large amounts of SOx, NOx and PM are released into the atmosphere from the exhaust gases. This makes HFO a 'dirty' fuel. Burning dirty fuel, therefore, puts these substances into the atmosphere which then harm human health and the ecosystem (Lindstad *et al.*, 2015).

Apart from SOx and NOx, ships also emit various other global warming pollutants such as carbon dioxide (CO2), black carbon (BC) and nitrous oxides (NO2). These pollutants all contribute to global climate change either directly, by acting as agents that trap heat in the atmosphere, or indirectly by aiding in the creation of additional greenhouse gases (GHG) (Harrould-Kolieb, 2008). There is a growing body of evidence that shows GHG is strongly linked to climate change, including the shrinking of the sea ice extent in the Arctic (Lindsey and Scott, 2019).

In the third greenhouse gas study by the IMO, it was estimated that ocean-going vessels released 796 million tonnes of CO2 in 2012, which accounts for approximately two percent of global anthropogenic CO2 emissions for that year (IMO, 2015c). It was estimated that without the introduction of measures to reduce emissions from shipping, the industry's CO2 emissions could grow between 50 percent and 250 percent by 2050.

The International Maritime Organisation (IMO), an agent of the United Nations (UN), has made amendments to its current regulations in order to reduce these pollutants and to and make shipping a more efficient and sustainable form of transportation (IMO, 2008). The IMO is responsible for the safety and security of shipping and the prevention of marine pollution by ships (Blanco-Bazán, 2004; IMO, 2016a). It provides the legal and technical framework for the shipping industry to become progressively cleaner and safer and has sponsored international conventions concerning pollution, such as MARPOL 73/78. Growing pressure from environmental bodies has been placed on the IMO in recent years to decrease air pollution from ships (IMO, 2013d). This has resulted in the Organisation implementing some regulatory and some market-based measures to improve ships' emission standards (Maestad *et al.*, 2000).

Apart from the IMO, the European Union (EU) is also actively involved in reducing atmospheric emissions from shipping through the introduction of its own regulatory measures. The EU is a unique economic and political union between 28 European countries, which is trying to reduce the impact of all pollution on the environment and human health within the EU. With regards to sulphur emissions, the EU has its own regulation, Directive 1999/32/EC, which addresses the sulphur content in marine fuel. In addition, some of the standards under the regulation were incorporated from the standards of the IMO. This includes the incorporation of IMO standards on the sulphur content allowed in marine fuel for ships operating in emission control areas. This was done to reinforce the strict international monitoring and enforcement regime in the EU. (EC, 2016a).

Therefore, the IMO and the EU (which include their member governments) are the *institutions* on which this research is based. Institutions are defined as systems of established and prevalent social rules that structure social interactions (Hodgson, 2006). An institution normally consists of an embodied structure of differentiated roles which are defined in terms of tasks, and rules regulating the performance of those tasks. The IMO and EU are both involved in establishing formal rules (air emission regulations) for the shipping industry.

According to Makkonen and Repka (2016), regulatory and commercial measures, taken by both the IMO and the EU, have been claimed to spur the development of green ship technology. Green ship technology is part of green innovation (see **Chapter 2**). Studies by Casper and Matraves (2003) and Shi *et al.* (2016) have established the link between innovation and regulation in the pharmaceutical and biomedical industry respectively, where regulation influences innovation capabilities of companies. Lee *et al.* (2004) found that regulation stimulated innovations in the automobile industry. Other studies by Lanjouw and Mody (1996); Lohmuller (2004) and Lanoie *et al.* (2011) also found that regulation encourages innovations within companies (see **Chapter 2.4.2**).

However, there is conflicting evidence that regulation does not always or naturally promote innovation activities in companies. In a report by the European Commission [EC] (2013), companies may lack the resources needed to invest in new innovations; which therefore, affects their ability to innovate. The type of regulatory approach also has an influence on innovation activities within companies (Lambertini and Tampieri, 2012; Pelkmans and Renda, 2014;

European Commission, 2016). Regulatory approaches that are prescriptive can hamper companies' innovation activities, while a more flexible approach can stimulate innovation. Furthermore, companies need to consider variables such as availability of funding, ease of appropriation, market size and risk before undertaking innovation activities (Pelkmans and Renda, 2014).

Blind (2012) argued that *"the impacts of regulation have been assessed as rather ambivalent for innovation in general"* (p.1). In other words, regulations can both encourage or discourage innovation in companies. The author also highlighted the lack of available literature that was aimed at understanding the effect of regulation on the ability of companies to innovate. Ultimately, Pelkmans and Renda (2014) states that the *"impact of regulation on innovation is an empirical, case-by-case question, and depends on the balance between innovation-inducing factors and innovation-constraining ones"* (p.7).

It is important to investigate the impact of regulation on innovation in the context of the shipping industry, as the industry is specifically affected by global trends that are unique to this transport sector or that have a stronger influence than is found in other industry and transport sectors (Department for Transport, 2019). The trends having an influence on the industry include climate change, new disruptive technologies, shifts in the world economy, long term changes in seaborne trade and the changing shape of the world population. This makes shipping different from other industries and justifies the need for this research to focus on the shipping industry.

The development of green ship technology is necessary as innovative marine equipment is needed to curb air pollution. The marine equipment sector is responsible for all products and services that are supplied for the building, conversion, maintenance of ships (seagoing and inland) and maritime structures. This includes technical services in the field of engineering, installation and commissioning, and ship maintenance (including repair) (European Marine Equipment Council [EMEC], 2010).

Regulatory or commercial drivers to reduce or prevent air pollution are also important as they will prevent ship-owners from running their ships on low-cost polluting fuels, unless those ships are fitted with abatement technology (such as scrubber units) that would result in lower emission rate (American Bureau of Shipping [ABS], 2013). It is therefore important to discover the variables that encourage or restrict innovation in the marine equipment sector, whilst also determining the roles that governments and institutional bodies, such as the EU and IMO, can play in supporting this.

1.3 Key definitions in this research

Due to the possibility of ambiguity behind the meanings of some of the key terms used in this research, the following definitions are applicable throughout this research:

Product innovation: A *good* (in the economic sense) or product that is new or significantly improved. This includes significant improvements in technical specifications, components and materials, software in the product, user-friendliness or other functional characteristics (Organisation for Economic Co-operation and Development [OECD], 2017).

Regulation: A rule or directive made and maintained by an authority.

1.4 Research questions

There are two research questions that need to be answered by the end of this study. The first research question is as follows:

- What are the variables that encourage or restrict innovation of green emission-reduction technology in the marine equipment sector?

This question then leads to a second research question:

- What impact do the institutions of both the EU and IMO have on the innovation of green emission-reduction technology in the EU?

1.5 Aims and objectives

The aim of this study is to discover variables that encourage or restrict innovation in the marine equipment sector within the EU and to apply this knowledge to the maritime EU and IMO institutional framework, thus further enabling cleaner air emissions from shipping. Six research objectives have been identified:

- To review available literature regarding institutions, innovation, and the current state of the marine equipment sector
- To review the literature and identify knowledge gaps between institutional policy and regulation, and innovation in manufacturing
- To synthesise current air quality regulation and policy of the EU and the IMO in relation to atmospheric emissions from shipping
- To discover the variables that encourage or restrict innovation
- To analyse the impact of both the EU and IMO, as organisations, on the innovation of green emission-reduction technology in the EU
- To make recommendations that will further enable cleaner air emissions from shipping

1.6 Research approach

The study aimed to gain a rich and complex understanding of the research topic and not to obtain information which can be generalised to other research areas. This research therefore was inductive in nature, aiming to develop a theory or look for a pattern of meaning from the data that were collected (Schutt, 2012). An explanatory synthesis, showing the type of regulation or policy that regulates each type of emissions, was also included to have a comprehensive overview of the subject matter.

Questionnaires (quantitative) were handed out to gather statistical data about responses, before the findings were used to guide the interview questions. Data for the questionnaires were analysed using the software available from the online platform on which the questionnaire was conducted (*SurveyMonkey*), and conclusions were drawn based on the data. As for the interview data, the software *NVivo* was used to analyse the results, which involves grouping similar themes together and carrying out content analysis.

1.7 Research justification

All transport, including shipping, releases harmful pollutants into the air. However, as ships can move bulk goods globally with great efficiency, shipping produces far fewer emissions of pollutants for each ton-mile of cargo compared to transportation by air, truck or rail. In spite of this advantage, more effort is needed to protect the environment because the total volume of marine shipment is so great that it has a significant impact overall (IMO, 2005a). Innovative products, which benefit the environment and contribute to environmental sustainability, need to be developed so that the goals of MARPOL Annex VI with regard to the reduction in global sulphur limits can be achieved (IMO, 2014c). This research is therefore important as the development of green ship technology will result in the shipping industry becoming more efficient and sustainable.

1.8 Research limitations

As this research is based on the stricter MARPOL Annex VI regulation coming into force on 1 January 2020, the focus is only on the air emissions from ships related to exhaust emissions that affect air quality. All other emissions by ships, such as from cargo or equipment related emissions, are excluded in this research.

The institutional framework of the IMO in relation to air emission regulation is examined in this research because the IMO is the body responsible for setting air emission standards for international shipping. The EU as an institution (which includes the UK for the purposes of this research) in relation to its shipping emission regulation is also examined, because it regulates shipping and the boundary of this research is limited to the area within the EU. All other regional institutions are therefore excluded from this research.

As for the measures and solutions that ship-owners can implement within their fleet to meet the sulphur regulation, this research is only focused on product innovation. Product innovation means goods (products) that are new or significantly improved, which ship-owners can fit or retrofit on their fleet. As such, innovations related to marketing, organisational or process innovation are not focused on in this research. Furthermore, although alternative fuel is not considered as a type of product innovation, it requires product innovation to be able to be burnt, so it will still be covered in this research (fuel alternatives are one of the solutions ship-owners can implement for the sulphur regulation).

All the limitations listed above are necessary and justifiable in this research as it allows for a narrow and specific focus.

1.9 Structure of the thesis

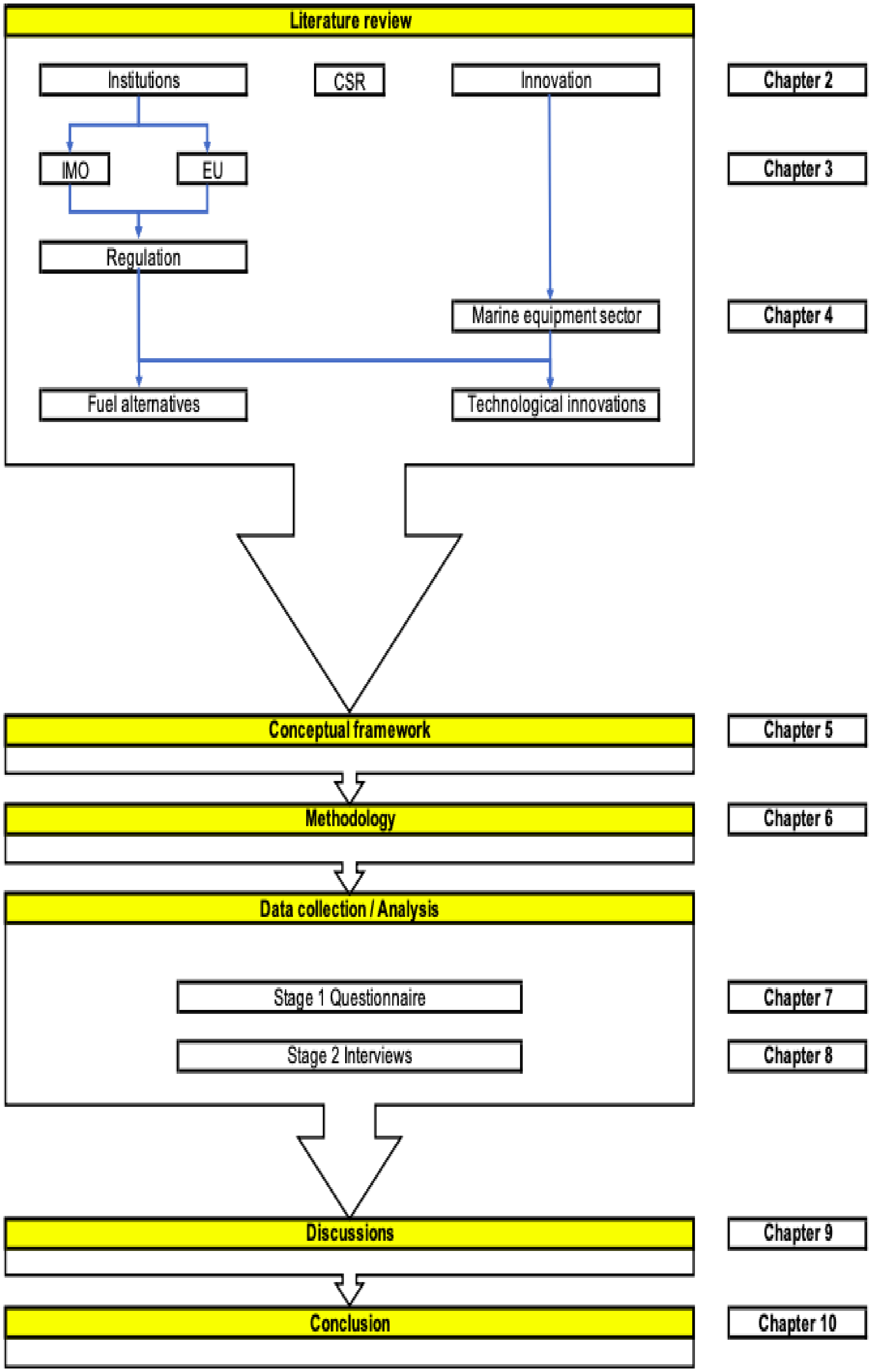


Figure 1-1 Structure of thesis

Chapter 1 has explained that global shipping activities have an adverse impact on society and the environment. It affects climate change and human health due to the burning of low-quality polluting bunker fuel in marine diesel engines. Measures therefore need to be in place in order to reduce or prevent pollution and to make shipping a more efficient and sustainable form of transportation. This makes it important to look at regulations concerning air pollution from ships as passed by the relevant institutions of the IMO and the EU.

Chapter 2 examines the broader sense of the term institution and corporate social responsibility (CSR). It then investigates the term green innovation, before identifying the variables that encourage or restrict green product innovation. By the end of Chapter 2, all the key theories, on which this research builds its foundations, are covered.

Chapter 3 covers the two organisations that have been selected and used for this research. Generic law and policy aspects are examined, before justifications for adopting both organisations as 'institutions' in this research are given. The chapter then examines the air pollution regulations and the ballast water management convention, before covering issues related to its enforcement. This chapter also provides a synthesise of air quality regulation and policy of the EU and the IMO, in relation to atmospheric emissions from shipping.

Chapter 4 looks at the marine equipment sector in the EU. The chapter then covers the different types of measures ship-owners can implement on their ships. This includes different types of alternative fuels and technological products available in the shipping industry. Lastly, this chapter examines the barriers to implementation of technological products by ship-owners.

Chapter 5 presents the summary of the literature review; drawing from all the different elements that were covered in earlier chapters. A conceptual framework for this research based on the summary is then provided. The framework is used to make conceptual distinctions and organising ideas that are relevant in this research. The chapter then highlights the research gap.

Chapter 6 concerns the methodological strategy for this research. Different research paradigms, approaches, methods and data types were examined. This chapter also identifies and justifies the method of data collection employed in this research. The methodological design which covers the blueprint for the collection, measurement and analysis of data in this research is also discussed. This chapter ends with a brief overview of research ethics.

Chapter 7 presents the first stage of the data collection method, which is questionnaires. This chapter covers the question design for both the ship-owner's questionnaire and the equipment manufacturer's questionnaire. The key stages of implementing the questionnaires are then discussed, before the chapter ends with the results and analysis from both sets of questionnaires.

Chapter 8 presents the second stage of the data collection method: semi-structured interviews. This chapter covers the question design for the interview, question justification, recruitment for interviews, and the procedures for conducting the interviews. This chapter ends with the results and analysis of the interviews.

Chapter 9 provides the discussions for this research, based on the results and analysis from both stage 1 and stage 2 of the data collection. The discussion is presented in a narrative style which includes: measures for ship-owners to comply with the regulation, drivers and barriers to innovation, overcoming financial barriers, industry’s preparedness to meet the regulation and applying the findings to the IMO and the EU as regulators. This chapter also covers the research contribution to theory development.

Chapter 10 concludes this research by summarising the key findings and demonstrating the achievement of the research aims and objectives. This chapter also covers research implications and suggestions for further research.

CHAPTER 2 THEORY ON INSTITUTION, CSR AND INNOVATION

2.1 Introduction

This chapter starts by looking into the definition of the term institutions and the different types of institutions. Following which, the chapter moves on to defining the term 'corporate social responsibility' (CSR) and looks at its relationship to regulation.

The chapter then looks at 'green innovation'. The different types of innovation: product, process, organisational and marketing, are then discussed before justification for the selected type of innovation used in this research is made. This chapter also covers the three levels of innovation: incremental, disruptive, and radical, before looking at determinants of green innovation. The chapter ends with a summary.

2.2 Institutions

In general, the term institution can refer to various things. People usually associate the word 'institution' with an organisation, or perhaps more commonly, a public organisation. This is reflected in the Oxford Dictionaries definition of an institution as *"an established official organisation having an important role in a society, such as the Church or parliament"* (Oxford University Press, 2018).

However, 'institution' can also refer to a more ambiguous phenomenon at a system level, which includes both rules and organisations – possibly a key role executed by the public sector (Skoog, 2005). This was reflected in the 2002 World Development Report, where institutions were referred to as *"rules, enforcement mechanisms and organisations"* (World Bank, 2002, p.6). This was also reflected by Hodgson (2001), who defines institutions as *"durable systems of established and embedded social rules and conventions that structure social interactions"* (p.295). As such, ‘institution’ here refers to the behavioural rules for social interaction (the term institutions and rules are used here interchangeably).

According to Vanberg (1994), these rules prescribe behaviour for actors in recurrent situations of interaction with other actors. Actors in this case may either be individuals or organisations. North (1990) states that organisations (economic, political or social organisations), are *“groups of individuals bound by some common purpose to achieve objectives”* (p.5). As such, when actors, either individuals or organisations are confronted with recurrent interaction problems, the rules facilitate their decision making and behaviour.

Complying with these rules is considered as a means for gaining legitimacy, decrease uncertainty, and increase the intelligibility of an organisation’s actions and activities (Berthod, 2016). These rules solve social interaction problems among actors. The institution forms ‘the rules of the game’, while the actors are the ‘players of the game’ (Jackson, 2009). Therefore, the key function of institutions is that they ‘facilitate order’ between actors and situations – bringing structure and stability to society (Kasper and Streit, 1998).

Boateng (2006) states that the rules influencing the behaviour of human actors include both *formal* and *informal* rules. Formal rules are intentionally designed by humans, and are codified in constitutions, statutes, regulations, laws, policies and other societal and cultural practices that exert compliance pressures (Meyer and Rowan, 1977; Boateng, 2006). The rules are often enforced by some external authority such as the police and the courts. Informal rules develop spontaneously and unintentionally over time through human interaction (Skoog, 2005). Informal rules are evident in social expectations such as customs, codes of conduct and behavioural norms; and can also take the form of unwritten conventions (Smajgl *et al.*, 2003).

Informal rules are usually self-enforced. According to Kasper and Streit (1998), actors who fails to follow these rules often face disapproval from other actors; to the extent of being expelled from the group. Institutions that are enforced becomes effective in terms of being applied and adhered to. Unenforced institutions on the other hand, are perceived to be ineffective in their influence on human behaviour and social interaction (Kasper and Streit, 1998; Galbiati and Vertova, 2014).

2.2.1 Types of institutions

Institutions prevail in all areas of social life and at all levels such as families, government agencies, businesses and churches. Institutions can also be categorised functionally, according to *the types of activity* that they regulate.

<u>Political institutions</u>

Political institutions regulate political activity and determines the characteristics of the political system (Rothstein, 1998). They include *"rules for how political power shall be distributed and among whom, procedures for political decision-making and for the electoral process"* (Skoog, 2005, p.21). Formal rules may be conveyed in a constitution, but informal political rules may also apply – for instance those of political culture and debate (Neumann and Almond, 1970).

<u>Economic institutions</u>

Economic institutions make up the economic system – the framework that regulates economic activity. Economic institutions can be broadly grouped into two categories:

1) Institutions that define the forms of ownership of the means of production; and
2) Institutions that define the mechanisms for resource allocation and co-ordination of economic activity.

Based on this, Skoog (2005) describe a market economic system as *“one where private property rights and the market mechanism dominate, while a centrally planned or directed economic system is dominated by state or collective ownership and bureaucratic/administrative co-ordination”* (p.21).

<u>Social or socio-cultural institutions</u>

Social or socio-cultural institutions regulate social and cultural interaction. This would mostly include informal rules such as determining mutual rights and obligations between society members (Skoog, 2005). According to Turner (1997), a social institution is *“a complex of positions, roles, norms and values lodged in particular types of social structures and organising relatively stable patterns of human activity with respect to fundamental problems in producing life-sustaining resources, in reproducing individuals, and in sustaining viable societal structures within a given environment”* (p.6). Hence, social institutions apply to the interaction among actors within a certain group or society.

Apart from categorising institutions according to *the types of activity* that they regulate, they can also be categorised on the basis of their *domain of applicability* in terms of geographical area or level (Skoog, 2005). There are global institutions (such as international conventions within the United Nations system), plurilateral institutions (as within the European Union), bilateral institutions (for instance, development co-operation agreements between two countries), and national institutions (such as municipal regulations). As such, *“there is no reason to restrict* *the prevalence of rules to the external context of organisations"* (Skoog, 2005, p.22).

2.3 Corporate social responsibility (CSR)

Corporate social responsibility (CSR) is a business concept that enables the *"production and distribution of wealth for the betterment of its stakeholders through the implementation and integration of ethical systems and sustainable management practices"* (Smith, 2011, p.10). To date, the definition of CSR continues to vary according to business aims, industry practices and even to meet the required purpose of academia (Smith, 2011; Hack *et al.*, 2014).

According to Hack *et al.* (2014), CSR is a *"multi-quantifiable tool* [which is used] *to represent responsible business activities, with direct links to annual accounting reports and performance indicators"* (p.46). In essence, it is a firm's multidimensional voluntary activities toward different stakeholders, which is beyond the narrow interest of the company (Wu *et al.*, 2018). This include those that are economic in nature, where companies provide return on investment to owners and shareholders, create new jobs, satisfy customers with goods and services of real value and discovering new resources, technological improvements and products (Lantos, 2001; Jamali and Mirshak, 2007).

Apart from economic responsibility, CSR business activities also include ethical responsibility, where companies do what is *"right, just and fair"* (Jamali and Mirshak, 2007, p.246). This include issues related to human rights (respecting peoples' moral rights, forced labour, child labour, equal opportunities, equal pay for equal work, gender equality), working conditions (protection of health, avoiding social harm, preventing social injury, compensation, working hours, training) and relations between employer and employee representatives (Lantos, 2001; Jamali and Mirshak, 2007; Preuss *et al.*, 2009). Novak (1996) states that such ethical responsibilities are embedded in religious convictions, moral traditions, humane principles and human rights commitments.

Finally, corporate CSR also entails legal responsibility. This involve complying with the laws and regulations and playing by the 'rules of the game' (Lantos, 2001; Jamali and Mirshak, 2007). According to Lantos (2001), laws regulating the conduct of companies exist as society does not often have the confidence that companies will fulfil their economic missions within the framework in doing what is right. As such, regulations are in place to regulate business conduct (Khumon, 2011). However, Bansal (2002) states that although regulation may successfully put pressure on companies to respond to an issue, it is challenging to ensure that it is applied in a fair and impartial manner.

Regulation has other shortcomings such as being of limited scope (unable to cover every possible contingency) and the possibility that companies are complying out of fear of being penalised and that it merely provides a moral minimum for business conduct (Lantos, 2001; Jamali and Mirshak, 2007; Skare and Golja, 2014; Baden, 2017). Furthermore, the reactive nature of regulations, where it usually states what ought not to be done by companies, leaves companies with little opportunity for them to be proactive. Regulations, therefore, *"circumscribe the limits of tolerable behaviour, but they neither define ethics nor do they legislate morality"* (Jamali and Mirshak, 2007, p.246).

When companies are faced with over-regulation, it also affects their ability to be proactive, as they *"often could do no more than comply with regulations"* (Bansal, 2002, p.127). This meant that companies were too focused on complying with regulations, which involves significant administrative burden, rather than channelling that focus on their process and product innovations (Bansal, 2002; Skare and Golja, 2014). Regulations may encourage innovations; but over-regulating may affect companies' innovation activities.

Green CSR

A new concept of CSR, 'green CSR', has emerged since the rise of environmental awareness requires global organisations to attach importance to environmental problems (Flammer, 2013; Fransen, 2013). More companies are actively making efforts to *"involve environmental concern into their corporate landscapes and strategic decision-making processes"* (p.268) in their bid to go green (Wu *et al.*, 2018). Green CSR exists in most companies which promotes the discussion on how the company provides their products and services in an ethically and environmentally sound performance (Yliskyla-Peuralahti and Gritsenko, 2014). As with CSR in general, green CSR has both ethical and compliance element.

Companies will have to consider of the environmental regulations already in existence or foreseeable in the future. These regulations are expected to lead to health and environmental benefits and encourages companies in finding new ways of doing things. From the theoretical perspective, Wu *et al.* (2018) states that being green is a catalyst for innovation as *"coping with environmental regulation requires the development and/or the adoption of new technologies to create favourable conditions for firms to trigger potential innovation"* (p.269). This means that companies will be more proactive in developing innovative working methods, innovative products, services or processes which are green.

According to Bansal (2002), it is important for environmental issues to be institutionalised in regulations and norms. This creates a 'level playing field' for companies to address the challenges of sustainable development. Some companies may also look forward to the challenges ahead and go beyond full compliance with current regulations, to improve their position in future regulatory negotiations (Reinhardt *et al.*, 2008).

According to Baden (2017), this results in these companies having a good environmental track record; consequently, enabling them to obtain insurance and financial backing with ease as they are considered to be low risk to insure or finance by relevant bodies. Over-compliance may also spur future regulation, where such companies have a competitive advantage over less adaptable companies (Reinhardt *et al.*, 2008). In essence, it is claimed that companies that proactively pursue CSR activities will engender a more creative, innovative and rewarding frame of mind which allows them to reap the reward in the future (Baden, 2017).

2.4 Green innovation

The UK's Department for Innovation, Universities and Skills (replaced by the Department for Business, Energy and Industrial Strategy in 2016) has defined innovation as:

> *"…the successful exploitation of new ideas, which can mean new to a company, organisation, industry or sector. It applies to products, services, business process and models, marketing and enabling technologies".* (Department for Innovation, Universities and Skills [DIUS], 2008, p.12)

According to Bessant and Tidd (2011), innovation is important to *"our customers/our shareholders/our business/our future and, most often, our survival and growth"* (p.4). It is a key driver of companies' productivity and comes in many forms such as new products, new or significantly improved production methods, new approaches to marketing and improved management techniques (European Bank for Reconstruction and Development [EBRD], 2014).

The definition of green innovation on the other hand, varies slightly from the general meaning of the term innovation. Most researchers are well acquainted with the concept of innovation. However, a standardised definition for the term green innovation is still disputed among academics (Cai and Zhou, 2014). According to Rennings (2000), the general definition of innovation is *"neutral concerning the content of change and open in all directions. In contrast, putting emphasis on innovation toward sustainable development is motivated by concern about direction and content of progress"* (p.322).

As such, the additional element of green innovation is that it reduces environmental burdens, where Oltra and Jean (2009) defined it as

> *"innovations that consist of new or modified processes, practices, systems and products which benefit the environment and so contribute to environmental sustainability"* (p.567).

In Driessen and Hillebrand (2002) however, the authors state that green innovation *"does not have to be developed with the goal of reducing the environmental burden"* (p.344). They took a rather pragmatic definition where innovations that yield significant environmental benefits can be termed as green innovation. Chen *et al.* (2006) on the other hand, define green innovation as

> *"hardware or software innovation that is related to green products or processes, including the innovation in technologies that are involved in energy-saving, pollution-prevention, waste recycling, green product designs, or corporate environmental management"* (p.333).

In other literature, various interchangeable terminologies were used by academics when describing green innovation. These terminologies are all related to the same topic and point to the same issue (Schiederig *et al.*, 2012). There are studies that uses the term environmental innovation, or eco-innovation, and one of the first to define the term is Fussler and James (1996):

> *"products and processes which provide customer and business value but significantly decrease environmental impacts"* (as cited in Calza *et al.*, 2017, p.3).

In other words, eco-innovation is products, services, and processes that deliver more value to producers and consumers while progressively reducing net environmental impacts (Berkel, 2007). There are also studies that uses the term sustainable innovation, where according to Charter and Clark (2007), is:

> *"a process where sustainability considerations (environmental, social, financial) are integrated into company systems from idea generation through to research and development (R&D) and commercialisation. This applies to products, services and technologies, as well as new business and organisation models"* (p.9).

It is important to consider that although eco-innovation and sustainable innovation are often used interchangeably, eco-innovation only *"addresses environmental and economic dimensions while sustainable innovation embraces these as well as the broader social and ethical dimensions"* (Charter and Clark, 2007, p.10).

It is evident that the definition of green innovation, eco-innovation and sustainable innovation includes *"all the changes in the product portfolio or in the production processes that tackles sustainability targets … implemented by firms to reduce their environmental footprint"* (Marchi, 2012, p.615). As such, the term 'green innovation' is used in this research for simplicity, with the understanding that it encompasses what may be describes as eco, environmental and sustainable innovation in other literature.

2.4.1 Types of innovation

As previously discussed, innovation, or green innovation, consists of various types of innovation: product, process, organisational, and marketing (see **Figure 2-2**). These different types of innovation are first examined in order to differentiate their characteristics, before the type of innovation appropriate for this research is considered and justified.

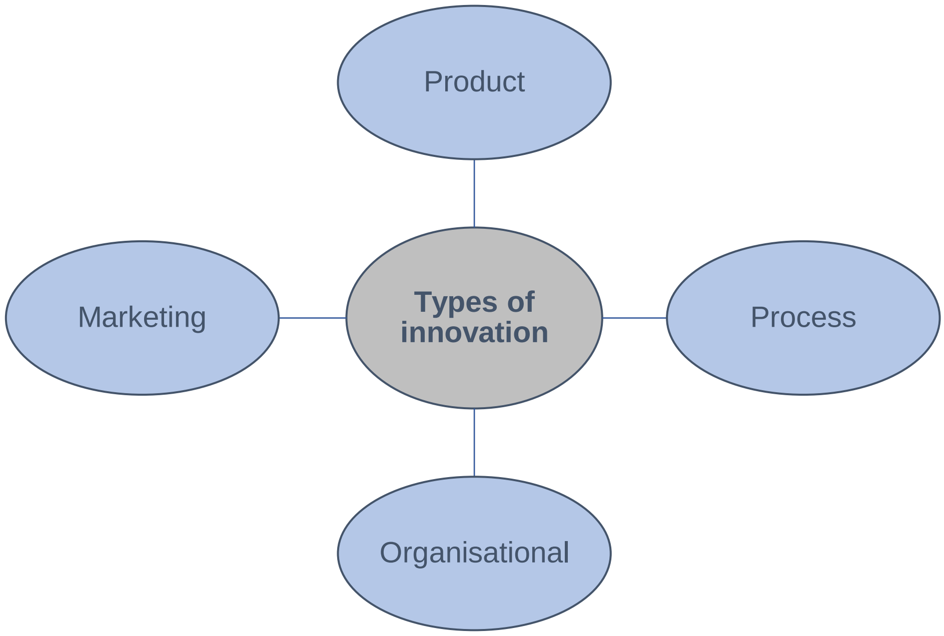


Figure 2-1 Types of innovation

Source: Author's own 2019

Product innovation

Product innovation is the creation of new products or services for end-users (Stucki *et al.*, 2018). Commonly, product innovation is assumed to consist of a ground-breaking technology which advances the global technological frontier (EBRD, 2014). In other words, although companies are constantly working on improving their products and introducing new ones, only a few of those products are considered as 'original' at the global level.

However, product innovations are also considered to be 'new' when they have been created using existing technologies with some customisation (EBRD, 2014). While these innovations are not considered ground-breaking, the product is still considered to be 'new' as it serves the needs of a different market. Product innovation is therefore *"a new or improved good or service that differs significantly* *from the firm's previous goods or services and that has been introduced on the market"* (OECD and Eurostat, 2018, p.70).

Product innovations must provide significant improvements to the good or service which can include changes to technical specifications, components and materials, incorporated software, user-friendliness, and other functional characteristics of goods and services (EBRD, 2014). In terms of green product innovation, it is those innovations that are aimed at *"reducing the product's environmental impact throughout production, use and disposal at the end of the product's life"* (Amores-Salvado *et al.*, 2014, p.357).

Process innovation

Process innovation refers to improvements in the manner in which goods and services are produced (Fagerberg, 2005). As defined by Bloch and Bugge (2013), process innovation is the *"implementation of a method for the production and provision of services and goods, that is new or significantly improved compared to existing process in* [the] *organisation"* (p.143). This may include significant improvements to the equipment, skills or information technology (IT) support function.

Examples of process innovation include automation of work that was used to be done manually, introduction of new software to manage inventories and introduction of new quality-control measures (EBRD, 2014). Process innovation can be intended by organisations to decrease the unit costs of production or delivery, to increase quality, or to produce or deliver new or significantly improved products (OECD and Eurostat, 2005).

In terms of green process innovation, it is a type of innovation that focuses on the techniques to produce and market goods or services, which have no or reduced impact on humans and the environment (Chen, 2011). Green process innovation therefore *"aims for energy consumption and ecological sustainability in addition to improving production efficiency"* (Tariq *et al.*, 2017, p.13).

Organisational innovation

Innovation does not always have to involve new technologies. It can also be in the form of organisational innovation, which primarily concerns people and the organisation of work flows. Bloch and Bugge (2013) define organisational innovation as the *"implementation of a new method for organising or managing work that differs significantly from existing methods in* [the] *organisation"* (p.143). This includes new or significant improvements to business practices, organising internal production, management systems, workplace organisation or external relations with other producers along the supply chain (Tenold and Theotokas, 2013; EBRD, 2014).

Organisational innovation may be intended by companies to increase their performance by reducing administrative costs or transaction costs, improve workplace satisfaction or reduce costs of supplies (OECD and Eurostat, 2005). It can also take the form of *"new management structures, the development of new internal routines and work practices, new supply chain relationships, strategic alliances and outsourcing"* (Windrum and Garcia-Goni, 2008, p.657).

Green organisational innovation therefore, is defined as *"the introduction of organisational methods and management systems for dealing with environmental issues in production and products"* (Kemp and Pearson, 2007, p.10). This may include pollution prevention schemes which are aimed at pollution prevention through more efficient operation of processes, and small changes to production plants.

Marketing innovation

Marketing innovation is the *“implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing”* (OECD and Eurostat, 2005, p.49). This form of innovation is aimed at better addressing customers’ needs, opening up new markets or repositioning companies’ product on the market (Tenold and Theotokas, 2013; EBRD, 2014).

The distinguishing feature of this type of innovation is the implementation of a marketing method not previously used by the company (OECD and Eurostat, 2005). As such, the new marketing concept must represent a significant departure from existing marketing methods. The use of new concepts for the promotion of a company’s goods and services may include product placement in films or television programmes, use of celebrity endorsements, establishment of customer loyalty cards or introducing variable pricing based on demand (EBRD, 2014).

In terms of green marketing innovation, it refers to *“the applications of marketing concepts and tools to facilitate exchanges that satisfy organisational and individual goals in such a way that they preserve, protect, and conserve the physical environment”* (Polonsky and Mintu-Wimsatt, 1995, p.2).

It is important to consider that even though product, process, organisational and marketing innovations cover a wide range of changes within an organisation, not every change can be considered as an innovation. Changes made within an organisation which include customisation, routine upgrades, regular seasonal changes and new pricing methods aimed solely at offering different prices to different groups of customers, are not considered as innovations (EBRD, 2014).

It is also important to consider that innovations have different degrees of originality, as the originality is intrinsic to the innovation. As such, innovations can be further classified based on their degree of originality: incremental and radical. Radical innovation is an innovation with a high degree of originality, *"which breaks with what existed previously and is the result of non-obvious paths or ideas"* (Souto, 2015, p.144).

Although radical innovations potentially *"offer huge profits and competitive advantage"* (Zakic *et al.*, 2008, p.18), they also involve great challenges and a higher risk level (Teece, 2010). In contrast, incremental innovation is an innovation with a low degree of originality and a lower risk level and cost. Incremental innovation does not break previous paths or ideas and carries a lower degree of originality as only significant improvements are made to previous paths or ideas (Souto, 2015).

For the purpose of this research, only product innovation is considered. This is due to the context of this research where the focus is on identifying green technological innovations for the marine equipment sector. These innovations for the marine equipment sector include both incremental and radical green innovations.

2.4.2 Variables that encourage or restrict innovation

Innovations in general support companies to advance and become more productive. Companies that do not change what they offers their customers or the way they create their products, are putting their own future in peril and at risk of being overtaken by other companies that innovate (EBRD, 2014). In order to prosper and remain competitive, companies need to innovate by seeking innovative solutions to emerging problems. As such, it is important to identify all other variables that encourages companies to innovate.

The number of studies and literature available on the variables that encourage innovation have been on the rise in recent years (Kammerer, 2009). However, different academics view these variables from different perspectives: technology push as opposed to demand/market pull (Rehfeld *et al.*, 2007), or from a perspective that focuses on internal factors vs. external factors (Cai and Zhou, 2014).

In this research, views from these different perspectives were explored in order to have a comprehensive assessment of the variables that encourage green product innovation within companies. In addition, it is also important to investigate the factors restricting companies from innovating. As such, the barriers to green product innovation within companies were also examined.

Variables encouraging innovation

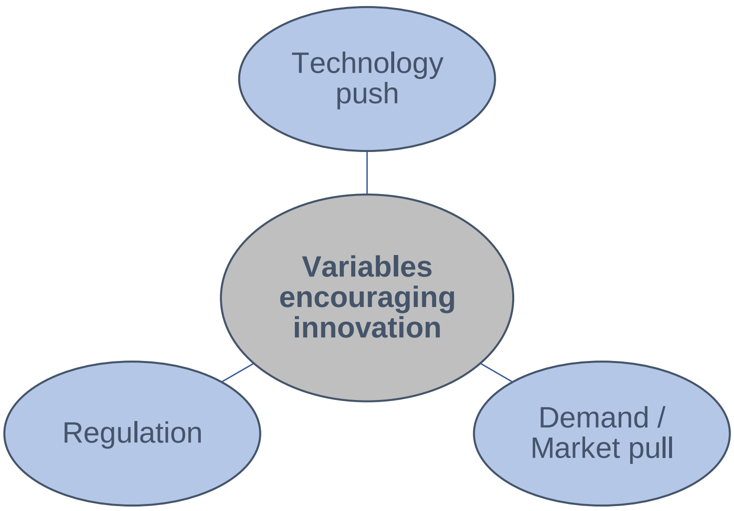


Figure 2-2 Variables encouraging innovation

Source: Author’s own 2019

Technology push

Technology push refers to a company’s technological capabilities. It comprises of their physical and knowledge capital stock to develop new products. Horbach (2008) found that *“the improvement of the technological capabilities (“knowledge capital”) by* [research and development] *triggers environmental innovations”* (p.163). In another study, Canon-de-Francia *et al.* (2007) found that *“availability of greater technical knowledge within a company moderates its vulnerability in the face of the demands of new environmental regulations”* (p.307). In order to build up a company’s knowledge capital stock, inputs such as investment in research and development or further education of the employees are necessary.

Companies that have highly developed innovation capacities are likely to achieve further innovation success in the future (Horbach, 2008). Baumol (2002) expressed this as *“innovation breeds innovation”* (p.284), where the availability of technological possibilities (increase human capital, available knowledge), encourage further innovations.

Demand/market pull

Demand pull, or market pull, is another determinant of green product innovation where the stimulus for innovation comes from the needs of society or a particular section of the market (Ghisetti *et al.*, 2017). These demands require manufacturers to conform to certain practices to improve their environmental performance and adopt proactive green innovation practices (Cai and Zhou, 2014; Dhull and Narwal, 2016).

In a study by Kammerer (2009), the author introduces the concept of customer benefits where green products also have private (environmental) benefits for customers (in addition to public benefits). Such customer benefits include *“cost* *and energy savings through more efficient appliances, improved product quality and durability, better repair, upgrade, and disposal possibilities, as well as reduced health impacts”* (Kammerer, 2009, p.2287). The study found that customer benefits play a key role in product innovation within companies, based on demand generated by consumers. However, not all companies *“in a sector attributes the same potential for customer benefit to a given environmental issue. This raises the question of what influences* [companies] *in identifying potential customer benefit of environmental issues”* (Kammerer, 2009, p.2292).

Horbach *et al.* (2012) however, found that existing studies indicate no strong stimulus for green product innovation from demand side, as green products were expensive (Rehfeld *et al.*, 2007). Furthermore, studies by Brohmann *et al.* (2009) and Bergh (2008) that argued consumers can also drive innovation, lack substantial empirical evidence. These studies show that demand/market pull is not a strong factor that encourages green product innovation within companies.

Regulation

Studies by Lanjouw and Mody (1996), Lohmuller (2004), Lanoie *et al.* (2011) and Horbach *et al.* (2012) all found regulation to be one of the factors that encourage companies to innovate. Furthermore, studies by Popp (2006) and Dangelico and Pujari (2010) provide evidence that companies’ innovation decision were mainly driven by national regulation. There is also the possibility that innovations within companies had been motivated by regulation abroad, as in the case of Japan where a catalytic converter had been developed due to air pollution regulation in the United States (Janicke and Jacob, 2004).

In addition, Arimura *et al.* (2007), found that stringent environmental regulation is generally an increasingly important driving force for innovation. Companies were becoming more likely to conduct environmental research and development with the aim of producing new products. As regulations demanding stricter emission standards are more prevalent in the global industry, companies *"are forced by* [these] *laws to develop new products"* (Lohmuller, 2004, p.229).

Barriers to innovation

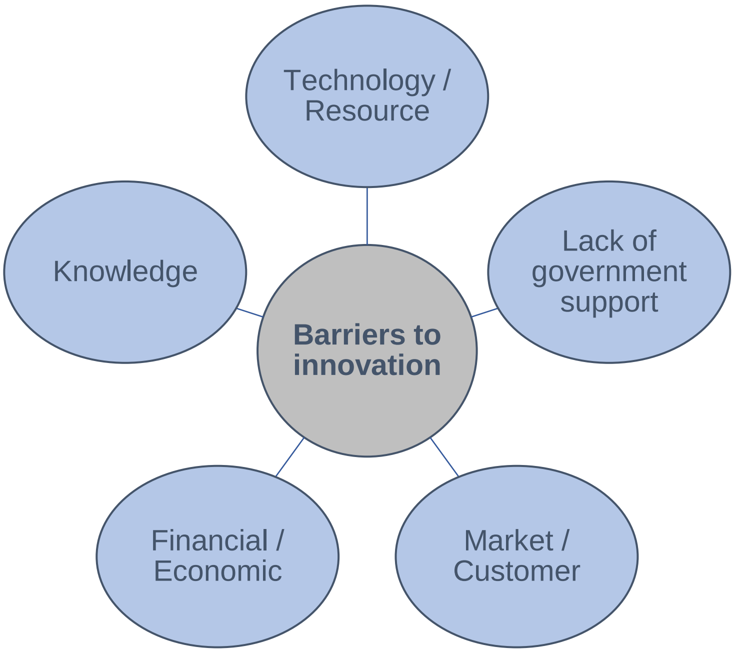


Figure 2-3 Barriers to innovation

Source: Author's own 2019

Technology and resources barriers

Technology and resources are both important factors for green product innovation and the lack of it may hinder a company's innovation activities (Abdullah *et al.*, 2016). Small and medium-sized enterprises (SME) are often found to be resource constrained, which hiders their innovation activities (Gupta and Barua, 2017). The major barriers identified by Gupta and Barua (2018) under this category involve lack of capabilities in research and development and green innovation; technological and market uncertainty and fear of failure related to green innovations; incompetent technologies to absorb green innovations developed by others; lack of new technology, materials, processes and skills to innovate; and lack of investment in research and development for green innovation.

Financial and economic barriers

The high costs associated with an innovation project is another barrier to innovation (Pinget *et al.*, 2015; Gupta and Barua, 2018). A study by Pinget *et al.* (2015) found that companies often face difficulties financing new innovations due to the lack of internal and external financial resources. As such, high costs and a lack of financial resources hampered company's environmental plans, especially in SMEs, which preclude them from adopting and practicing green innovations (Ghisetti *et al.*, 2017).

The major financial barriers to green innovation, especially for SMEs, include: lack of access to government subsidies and financial incentives; high change over costs from traditional to green system; and no economies of scale for green products due to lesser demand (Gupta and Barua, 2018). Unavailability of bank loans to promote green practices also hinders companies innovation activities (Abdullah *et al.*, 2016)

Lack of government support

Government regulations and policies often act as impediments for green innovation due to their stringent nature and unclear procedures (Abdullah *et al.*, 2016; Gupta and Barua, 2018). As such, companies are often demotivated to carry out green innovation due to the lack of government support (Runhaar *et al.*, 2008).

Market and customer related barriers

According to Ghisetti *et al.* (2017), companies, especially SMEs, do not adopt green practices due to the high costs associated with producing green products. Furthermore, market uncertainties and uncertain returns on investment also act as impediments for green innovation (Karakaya *et al.*, 2014). Empirical evidence shows that some innovation requires a lengthy period before they are adopted. This may be due to green products having commercialisation problems, such as being more expensive for consumers to purchase as compared to conventional substitutes (Rehfeld *et al.*, 2007).

Knowledge barriers

Knowledge barriers *"pertain to limited access to information about technology and skilled labour"* (Pinget *et al.*, 2015, p.138). This affects a company's ability to find alternative solutions to design new technologies. A study by Silva *et al.* (2007) also identified lack of technical expertise and knowledge as barriers to innovation.

2.5 Summary

The first part of this chapter has covered the general definition of the term institutions and the types of institutions available. Following that, the concept of corporate social responsibility (CSR) has covered. The dimensions of CSR are economic responsibility, ethical responsibility, legal responsibility and green ethical considerations. Lastly, the definition of innovation and green innovation was covered, in addition to identifying the variables that encourage or restrict green product innovation. This chapter has covered the theoretical foundations from which this research is based.

CHAPTER 3 POLLUTION FROM SHIPS – INSTITUTIONS INVOLVED

3.1 Introduction

This chapter builds on from the theoretical foundations covered in **Chapter 2**. The first part of this chapter identifies the two institutions that were selected for the purpose of this research, before the specific air pollution regulations, on which this research is based, are examined. As a comparator to the air pollution regulation, IMO's ballast water management convention, is included. Lastly, the fuel assessment study to determine the availability of fuel oil with a sulphur content of 0.5 percent m/m (mass by mass) or less in 2020, is also included.

The next part of this chapter seeks to identify the effect each regulated pollution has on human health and the environment. This information provides a basic understanding of the extent and seriousness each pollutant has on society, and the reason for the stricter regulation being imposed. The data is then synthesised according to the IMO and EU regulation it falls under, presented in a tabular format. This table gives a comprehensive overview of specific IMO and EU regulation regulating each pollutant and the standards that needs to be adhered to.

3.2 International Maritime Organisation

The shipping industry is a global industry; evident from the diversity of stakeholders of all nationalities that are involved in the design, construction, ownership, operation and crewing of a typical ocean-going ships, not to mention the classification, finance, insurance and cargo ownership aspects (IMO, 2013a). The whole of a ship working life expectancy is spent transporting cargoes between different countries, regions and continents that are characterised by different legal jurisdiction which are often far away from the country of registry

(McLaughlin, 2010). Furthermore, it is often the case that the country of ownership of the ship is different from the country of flag registration.

Unlike land-based industries, which are regulated mainly through national legislation and standards, the shipping industry requires international regulations because ships are mobile. This is to ensure the shipping industry continues to function as the principal vehicle for the movement of more than 90 percent of global trade (IMO, 2013a). As such, the global nature of the shipping industry makes it important to develop and maintain a comprehensive framework for safe, secure, efficient and environmentally sound shipping that is applicable universally to all ships. This led to the establishment of the International Maritime Organisation (IMO), in response to the complexities of jurisdiction which operates in the shipping industry (McLaughlin, 2010).

The IMO is a specialised agency of the United Nations (UN) responsible for drafting legal instruments, in addition to facilitating technical co-operation for the protection of the marine environment.

The IMO plays an important role in ensuring lives at sea are not put at risk and the environment is not polluted by ships' operations (Blanco-Bazán, 2004). This is summed up in the Organisation's mission statement: *safe, secure and efficient shipping on clean oceans*. The Organisation has been working to reduce harmful impacts from shipping activities on the environment since the 1960s. The overall purpose of the IMO is summarised under Article 1(s) of the IMO Convention:

> *To provide machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships.*

The structure within the IMO consists of an Assembly, a Council and five main Committees: Maritime Safety Committee (MSC); Legal Committee; Marine Environment Protection Committee (MEPC); Technical Co-operation Committee and Facilitation Committee and a number of Sub-Committees support the work of the main technical committees (Karim, 2014). All these organs have a vital role to play with regards to the prevention of marine pollution from ships. However, the MEPC is the most important organ responsible on that matter (Mensah, 2007).

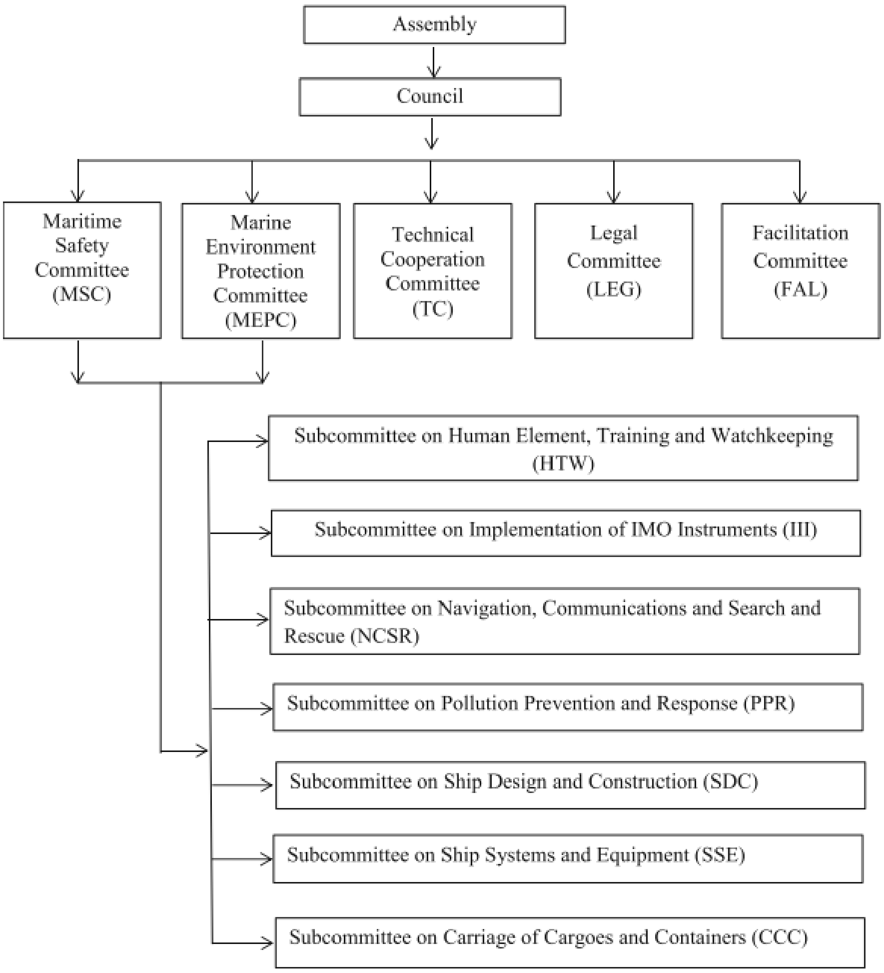


Figure 3-1 IMO institutional framework

Source: Karim 2014 p.22

The MEPC has the power to deliberate on all issues concerning the prevention and control of marine pollution from ships that are within the scope of the IMO.

The Committee is entrusted with the *"responsibility of performing functions conferred upon the Organisation under international legal instruments for the prevention and control of the marine pollution"* from ship (Karim, 2014, p.25). Other responsibilities of the Committee include: matters related to the adoption and amendment of regulations or other provisions stipulated in those legal instruments; promoting measures for the facilitation of enforcement of international marine environmental conventions; gathering of scientific, technical and any other practical information regarding marine pollution; and promoting co-operation with regional organisations regarding marine environmental matters.

3.2.1 Law-making

Aside from the main organs of the IMO, the law-making process within the Organisation involves other actors from three different types of entities: member states (including associate members), inter-governmental organisations as observer organisations and international non-governmental organisations as organisations with consultative status (Andersson *et al.*, 2016).

<u>Member States:</u> To date, the IMO has 174 Member States and three Associate Members representing all regions of the world (IMO, 2019b). Although all states are eligible to become members of the IMO, they are subjected to the relevant provisions of the IMO Convention. Associate members are any territory or group within a member state that are eligible to apply, *"if it is a territory to which the Convention has been made applicable under Article 72, by the Member having responsibility for its international relations or by the UN"* (Karim, 2014, p.16). Associate members have no formal decision-making powers and are excluded from membership in the Council (Andersson *et al.*, 2016). Being formal members of the IMO, member states are the dominant actors out of all the entities involved in the process of drafting conventions. As such, only member states have a vote

on decisions related to the implementation, modification or amendment of any working treaties of the IMO (Harrison, 2009).

Inter-governmental organisations: Apart from co-operating between IMO and any specialised agency of the UN regarding matters of common interest, the IMO Convention also provides co-operation with other inter-governmental organisations should their concern and activities relates to the purpose of the Organisation (Andersson *et al.*, 2016). These organisations have an observer status that allows them to access documents, attend meetings and participate in discussions. However, they do not hold any formal decision-making powers at the IMO.

Non-governmental organisations: Non-governmental organisations, or non-state actors, consists of multi-national corporations, trade associations and research-oriented associations. These organisations, representing a variety of interests in IMO Convention, may be granted consultative status if that organisation is able to make a substantial contribution to the work of the IMO (Karim, 2014). Having this status allows the organisation to access documents and attend meetings. Though these organisations plays a significant role in IMO law-making process, they are not entrusted with voting rights and have no formal way to influence the outcome of the decision-making process (Harrison, 2009). Furthermore, unless they can convince a government to introduce a proposal on their behalf, they are also prohibited from introducing new agenda items.

All regulations and standards need to be agreed, adopted and implemented on an international basis for the shipping industry to operate effectively (IMO, 2016a). However, facilitating the adoption and amendment of international regulation involves a lengthy and distinctive process. With regards to amendments, the operational requirements of the regulation need to be revised at the IMO, before changes to the operative technical standards can be made (Beattie, 1985). Amendments to any treaties are to be adopted by a diplomatic conference assembled by the IMO. However, the IMO Legal Committee may itself adopt amendments to treaties using a special tacit amendment procedure (Harrison, 2009).

Although the regulatory framework is developed and maintained by the IMO, the Organisation is only empowered with administrative power related to these purposes. The Member States are the ones that will be required to implement the conventions adopted in their national legislation, for it to be enforceable within their country.

3.2.2 IMO as an institution

The IMO sponsors a number of international conventions related to pollution and implements regulatory and market-based measures for the global shipping industry (Kopela, 2017). The institutional framework of the IMO is where the global shipping industry gets its reference from, in complying with the rules and regulations established by the Organisation that exert compliance pressures. It consists of an embodied structure of differentiated roles defined in terms of tasks and rules regulating the performance of those tasks (Hadjistassou, 2004).

Member states to the Convention are expected to follow the formal rule sets established in the structure of the IMO. However, states will need to establish these rules set by the IMO as laws under their own respective legal systems. Individuals from the respective states must then adhere to the rules and laws under which they are governed.

The Organisation's regulatory framework for shipping activities is a crucial pre-condition for the implementation of any shipping intervention measures, as it forms the basis for their success and sustainability. As such, the Organisation was selected as one of the institutions for this research as it represents the governing body responsible for global issues related to shipping activities.

3.3 European Union

The European Union (EU) is a unique economic and political partnership between 28 European countries. The initial step undertaken by the predecessor of the EU, which was created in the aftermath of the Second World War, was fostering economic co-operation. This was done based on the idea that *"countries that trade with one another become economically interdependent and so more likely to avoid conflict"* (European Union [EU], 2014b, p.1). As such, it led to the establishment of the European Economic Community (EEC) in 1958. However, the EEC has since evolved from a purely economic union into an organisation spanning policy areas, from climate, environment and health to external relations and security, justice and migration. A name change from the EEC to the EU was carried out in 1993 to reflect this (Ammon, 1996).

The EU maritime transport policy was slow to develop, even though Article 3(f) of the European Commission (EC) Treaty requires member states to create a Common Transport Policy (CTP) (Greaves, 2000; Greaves and McMahon, 2007; Butcher, 2010). This was due to the focus of the Treaty transport provisions being on inland modes of transport (road, rail and inland waterways). The development of the CTP is crucial as it allows for the free movement of goods, services and persons among member states. The CTP is also developed to be in line with the goal of the EC Treaty: having an all-embracing economic union (Greaves, 2000).

Most of the maritime transport treaties and conventions are regulated internationally, due to the very nature of it being an international mode of transportation. The international treaties and conventions are mostly negotiated and concluded within the IMO (Greaves and McMahon, 2007). Some EU member states and members of the international community were initially reluctant to handover their sovereignty in this field of transport to the EU (Meunier and Nicolaidis, 1999; Greaves and McMahon, 2007). Eventually, member states gradually changed their perception of the Union's ability and competency in regulating this mode of transport after the occurrence of two main events.

The first event was due to the mid-1980s push to establish an internal market by 1992, which placed all modes of transport at the centre of the project (Greaves and McMahon, 2007). Initially, it was not possible to establish a geographical market stretching from the Atlantic to Eastern European countries and from the North Sea to the Mediterranean, where goods, services, people and capital were able to circulate freely and in a competitive manner, without the EU having to seriously address the transport issues (Greaves, 2000; Greaves and McMahon, 2007). As a result, *"a number of important legislative proposals affecting the provisions of maritime transport services were adopted and implemented during that period"* (Greaves and McMahon, 2007, p.415).

The second event was due to a number of serious marine accidents that took place in EU's coastal waters within a span of 20 years. Notable marine accidents such as *Herald of Free Enterprise* in 1987, *Exxon Valdez* in 1989 and *Estonia* in 1994, further prompted the development of a maritime transport policy (Greaves and McMahon, 2007). These accidents, involving oil tankers and passenger ferries, caused vast environmental coastal damage and loss of lives respectively.

As a result, they adopted a large number of legislative measures by the EU in relation to maritime safety and security.

As in most federations, the member states of the EU retain all powers not explicitly handed to the Union. In some areas however, the EU does not have exclusive competence; it only plays a supporting role. In such cases, member states *“may enact legislation only where the EU has not, or they may elaborate the laws of the EU”* (McLaughlin, 2010, p.8). Different competencies may also be used in different ways. The distribution of competences in many policy areas between Member States and the Union is divided into the following three categories (EU, 2016):

<u>Exclusive competence:</u> The Union has exclusive competence to make directives and conclude international agreements when provided for in a Union legislative act.

<u>Shared competence:</u> Member States cannot exercise competence in areas where the Union has done so.

<u>Supporting competence:</u> The Union can carry out actions to support, coordinate or supplement Member States’ actions.

3.3.1 Law-making

Some of the key institutions within the EU include: the Court of Justice of the European Union; the European Parliament; the European Central Bank; the European Council; the Council of the European Union and the European Commission (EU, 2014a). Although decision-making at EU level involves various European institution, the three main institutions involved in the law-making process within the EU are (EU, 2018):

The European Parliament: which represents the EU's citizens and is directly elected by them.

The Council of the European Union: which represents the governments of the EU member states.

The European Commission: which represents the interest of the Union as a whole.

Through the 'Ordinary Legislative Procedure', these three institutions produce the policies and laws that are applicable throughout the EU. The Council defines the general political direction and priorities of the EU, but it does not exercise legislative functions. In principle, the Commission proposes new laws and it is the Parliament and Council that adopt them. The member states and the Commission then implement them, and the Commission ensures that the laws are properly applied and implemented (EU, 2018).

There are several types of legal acts which are applied in different ways (EC, 2012c):

Regulation: a law that does not need to be passed into national law by member states; it is directly applicable and binding in all member states.

Directive: a law that must be transposed into national law to become effective; it binds member states to achieve a particular objective.

Decision: can be addressed to member states, groups of people or even individuals; binding in its entirety.

Recommendations/opinions: no biding force.

3.3.2 EU as an institution

The EU is the second institution used in this research. It is used to investigate the relationship between institutions and innovation activities in the marine equipment sector within the EU. The reason for selecting EU as an institution lies in the fact that the Union regulates shipping activities within the EU. This is in line with the focus area of this research, which is limited to the EU.

Member states behave in response to the basic components of the institutional structure, with regards to the arrangements of rules and incentives set out related to maritime transport.

Like the IMO, the Union's framework for matters related to shipping activities is also a crucial pre-condition for the implementation of any shipping intervention measures. The framework forms the basis for the success and sustainability of the measures adopted. As such, the EU was selected as the second institution for this research as it represents the governing body responsible for regional matters related to shipping activities.

3.4 Air pollution regulation

This section examines the air pollution regulation of the IMO and the EU. In addition, the study commissioned by the IMO on the availability of the required fuel (low sulphur fuel), is also examined. This is due to the outcome of the study having an influence on the enforcement date of the sulphur regulation; either 1 January 2020 or 1 January 2025.

3.4.1 IMO MARPOL Annex VI

The International Convention for the Prevention of Pollution from Ships (MARPOL) is adopted on 2 November 1973. It is the main international convention that deals with the prevention of pollution of the marine environment by ships, from operational or accidental causes (Mensah, 2007; IMO, 2011a). The Convention has yet to enter into force when the Protocol of 1978 was adopted; in response to a series of tanker accidents between 1976-1977 (IMO, 2011a; Ventikos *et al.*, 2019). This has led to the 1978 MARPOL Protocol absorbing the parent Convention. The combined instrument eventually entered into force on 2 October 1983 (IMO, 2011a).

Another protocol was adopted in 1997 to amend the 1973 Convention, after recalling principle 15 of the Rio Declaration in Environment and Development for implementing of precautionary measures for reducing of air emissions (Tay, 2011). This was the addition of a new Annex VI which entered into force on 19 May 2005 (IMO, 2013c). The MARPOL Convention has been updated by amendments throughout the years, in order to keep pace with the rapidly evolving technology in the shipping world and to broaden the scope of MARPOL Annex VI (IMO, 2014b). For instance, guidelines adopted at the 62nd MEPC session had seen that the shipping industry is ready to make effort to go beyond just mitigating the aftermath effect of the pollution from ships. The new requirements involved eliminating or reducing the level of emissions from the conceptual stage of the ship, where the ship's design is still in the designing stage (for new ships) and controlling the operational efficiency of existing ships.

MARPOL Annex VI covers regulations for the prevention of air pollution from ships. It applies to all ships (unless expressly stated otherwise in several regulations) and controls a range of different pollutants that come together with certain characteristics related to ship operation, which in itself can result in air pollution (IMO, 2013b). To indicate compliance with the relevant requirements of Annex VI, ships of 400 gross tonnages and above will be issued with an

International Air Pollution Prevention (IAPP) Certificate by the flag State, which is a Party to Annex VI (IMO, 2013b).

At the 53rd session of the MEPC in July 2005, an agreement was made to revise MARPOL Annex VI with the aim of significantly strengthening the emission limits in light of technological improvements and implementation experience (IMO, 2005b). The result from three years of examination has successfully led to the adoption of the revised MARPOL Annex VI and the associated nitrogen oxides (NOx) Technical Code 2008 (entered into force on 1 July 2010) at the 58th session of the MEPC in October 2008 (IMO, 2008). The revised Annex VI sets limits on sulphur oxides (SOx) and NOx emissions from ship exhausts as well as particulate matter (PM) and prohibits deliberate emissions of ozone depleting substances, such as hydro-chlorofluorocarbons.

According to IMO (2013b), the revised control within Annex VI covers:

- Ozone-depleting substances released from refrigeration and fire-fighting systems and equipment. Such substances are also contained in some types of insulation foams;
- Nitrogen oxides from diesel engine combustion;
- Sulphur oxides and particulate matter emissions from the combustion of fuel oils which contains sulphur;
- Volatile organic compounds, the hydrocarbon vapours displaced from tanker cargo spaces;
- Shipboard incineration; and
- Fuel oil quality in so far as it relates to a number of air quality issues.

To reduce the amount of CO2 emissions from international shipping, the IMO adopted mandatory technical and operational energy efficiency measures in 2011 (IMO, 2018a). These mandatory measures, in the form of Energy Efficiency

Design Index (EEDI) and the Ship Energy Efficiency Management Plan (SEEMP), entered into force on 1 January 2013.

3.4.1.1 SOx emissions control

MARPOL Annex VI, Regulation 14 dictates the requirements of SOx in terms of the fuel oil used onboard ships. The main 2008 amendments to MARPOL Annex VI were to progressively reduce the emissions of SOx, NOx and particulate matter globally and the introduction of Emission Control Areas (ECAs) (Fagerholt and Psaraftis, 2015). ECAs is an international system that is intended to reduce emissions of those pollutants further in designated sea areas, such as in the Baltic Sea, North Sea, North America and the Caribbean Sea (Hughes, 2011; Fagerholt and Psaraftis, 2015).

The global sulphur limit under Regulation 14.1 of the revised MARPOL Annex VI was reduced from 4.5 percent to 3.5 percent on 1 January 2012 and will gradually be reduced to 0.5 percent effective from 1 January 2020. On the other hand, the applicable SOx and particulate matter limits in ECAs under Regulation 14.4 of Annex VI were reduced from 1.5 percent to 1.0 percent from the beginning of 1 July 2010 and were further reduced to 0.1 percent effective from 1 January 2015 (Tay, 2011; IMO, 2014c). **Figure 3-4** makes a comparison of the fuel standards requirements globally and in ECAs from 2010 to 2020.

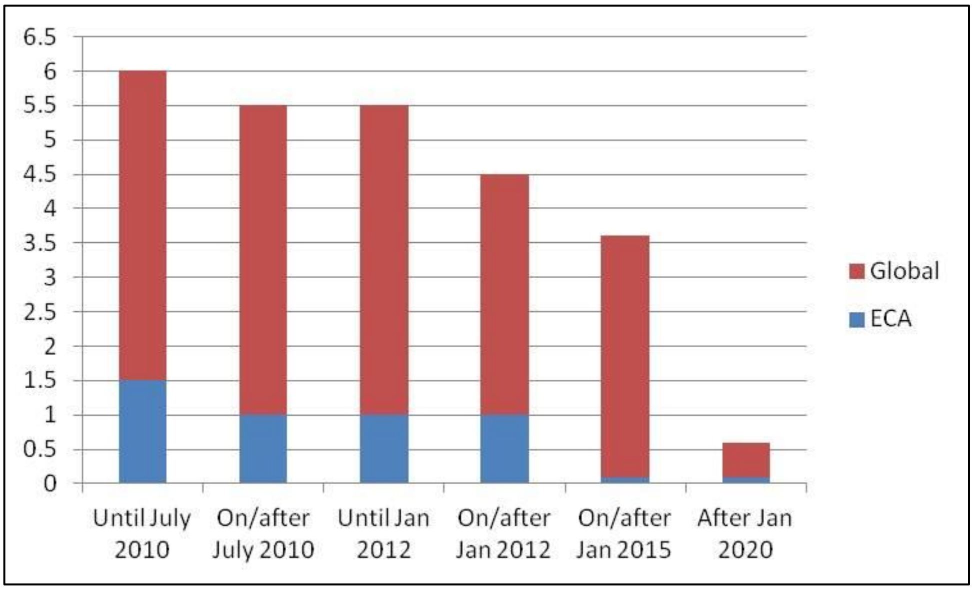


Figure 3-2 MARPOL Annex VI fuel sulphur limits in percentage (%)

Source: Author's own (based on data from MARPOL Annex VI) 2019

3.4.1.2 NOx emissions control

Aside from adopting a new protocol (Annex VI) at the 17th Session of the IMO Assembly in 1997, a total of eight resolutions were also adopted. Of these, resolution two provides the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines (NOx Technical Code). The aim of the Technical Code is to progressively reduce NOx emissions from marine diesel engines installed on ships in phases.

The first phase, 'Tier 1' emission limit, applies to engines that were installed on or after 1 January 1990 to 1 January 2000. For engines installed on or after 1 January 2011, a 'Tier II' emission limit applies, whereas a more stringent 'Tier III' emission limit applies for engines installed on or after 1 January 2016 operating in ECAs such as in North America and the Caribbean Sea (IMO, 2014c). **Figure 3-5** shows the timeline for the implementation of the various Tier for marine diesel engine on new ships.

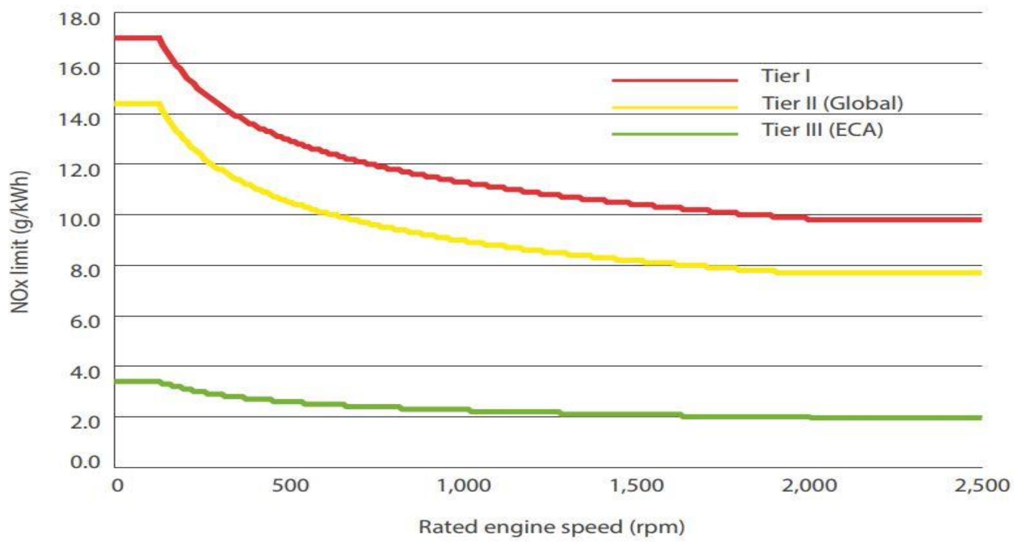


Figure 3-3 MARPOL Annex VI NOx emission standards for new ship engines

Source: Lloyd's Register 2015 p.8

With regards to the revised NOx Technical Code 2008, a new chapter based on the agreed approach for regulation of existing (pre-2000) engines established in Annex VI was included. Also includes are provisions for a direct measurement and monitoring method, a certification procedure for existing engines, and test cycles to be applied to Tier II and Tier III engines (IMO, 2014c). It is expected that the revised measures will have significant beneficial impacts on the atmospheric environment and on human health.

In 2011, IMO adopted mandatory technical and operational energy efficiency measures which will significantly reduce the amount of greenhouse gas emissions from ships (IMO, 2011b). These measures were included in Annex VI and entered into force on 1 January 2013. Ships of 400 gross tonnages and above will be issued with an International Energy Efficiency (IEE) Certificate (IMO, 2013b).

3.4.1.3 Sulphur emission control areas

SOx emission control areas (SECAs) was first established in 19 May 2005 and became enforceable on 19 May 2006 in Baltic Sea, after agreement at the IMO and incorporation into European law. Subsequently, the North Sea and English Channel became the second SECA under European Commission Directive 2005/33 in August 2007. The purpose of designating SECAs is to establish more stringent controls on SOx emissions from ships as it causes the acidification of the atmosphere which results in acid rain.

In 2008 however, amendments were made to MARPOL Annex VI and one of the amendments was the change to the name and definition of an emission control area from SECA to ECA (emission control area) (Polish Register of Shipping [PRS], 2009). ECA is now defined as an area where special mandatory measures for emissions from ships is required to prevent, reduce and control air pollution from NOx or SOx and PM or all three types of emissions and their attendant adverse impacts on human health and the environment. Following this change, North America was one of the first areas designated by IMO as ECA which entered into force in August 2012. The establishment and adoption of either SECA or ECA can be considered to have major health and environmental benefits for the world, particularly for populations living close to ports and coasts as it significantly reduces the amount of harmful emissions from ships.

Under the revised Annex VI, national governments were also encouraged to individually or collectively seek approval from the IMO for the introduction of new ECAs to reduce emissions in designated geographical coastal areas. A country or countries wanting to establish an ECA in a nearby ocean could do so by submitting proposal documents to the MEPC. This could potentially increase the ECA boundary to make the regulation applicable to more areas globally.

However, this is subjected to approval of the proposal by the MEPC who surveys the documents in accordance to eight criteria written in Appendix III of the revised Annex VI.

The eight criteria required for designation of an ECA are as follows: (1) a clear delineation of the proposed area of application; (2) the type or types of emission(s) that is or are being proposed for control; (3) a description of the human populations and environmental areas at risk from the impacts of ship emissions; (4) an assessment that emissions from ships operating in the proposed area of application are contributing to ambient concentrations of air pollution or to adverse environmental impacts; (5) relevant information on meteorological, topographical, geological, oceanographic, morphological, or other conditions that contribute to ambient concentrations of air pollution or adverse environmental impacts; (6) the nature of the ship traffic in the proposed ECA; (7) a description of the control measures taken by the proposing Party or Parties addressing land-based sources of NOx, SOx and particulate matter emissions; and (8) the relative costs of reducing emissions from ships when compared with land-based controls, and the economic impacts on shipping engaged in international trade (Akira, 2013).

Once the proposal has been accepted after careful deliberation of the merits for establishing the ECA, the country or countries can then establish an ECA in their ocean. MEPC would then revise Annex VI to designate the proposed area an ECA (Akira, 2013). As such, it is foreseeable in the future that more coastal areas could be expected to be designated as ECAs. An increase in the designated ECAs would therefore require additional research and projections on the availability of low sulphur fuel.

Figure 3-4 Map of current and possible future ECAs

Source: Rickmers-Linie 2014

3.4.1.4 Energy efficiency measures

Energy efficiency measures to curb CO2 emissions was added in a new Chapter 4 of MARPOL Annex VI entitled “Regulations on energy efficiency for ships”. It consists of two main measures: EEDI and SEEMP, and applies to all ships of 400 gross tonnage and above, irrespective of flag and ownership (IMO, 2018c).

The EEDI is the most important technical measure aimed at promoting the use of more energy efficient equipment and engines (IMO, 2018b). It requires all new ships built from 2013 onwards to comply with minimum mandatory energy efficiency performance levels. This performance level increases in stringency every five years, up until 2030, to keep pace with technological developments of new efficiency and reduction measures (Rehmatulla *et al.*, 2017).

SEEMP on the other hand, is an operational measure that establishes a mechanism for shipowners to improve energy efficiency of both new and existing ships in a cost-effective manner (IMO, 2018c). These measures include weather routing, speed optimisation and just-in-time arrival in ports. The SEEMP also provides an approach for shipping companies to improve the ship's energy efficiency by monitoring the performance of the ship over a certain period using the Energy Efficiency Operational Indicator (EEOI) as a benchmark level (Perera and Mo, 2016). The EEOI *"enables operators to measure the fuel efficiency of a ship in operation and to gauge the effect of any changes in operation"* (IMO, 2018b, p.1).

3.4.2 EU sulphur directives

The EU has its own regulations with regards to sulphur content in certain liquid fuels such as diesel fuels that are used in road vehicles and gas oils that are used for off-road transport. Directive 1999/32/EC initially addresses the sulphur content of gas oils but has since included heavy fuel oil, heating oil and marine fuels after the EU has incorporated the rules adopted by the IMO into its own law. One of the aims of incorporating IMO standards into EU law was to reinforce the strict international monitoring and enforcement regime (EC, 2016a).

Since then, significant revision was done to the Directive because of the Commission's strategy in reducing atmospheric emissions from seagoing ships. The changes were reflected in Directive 2005/33/EC which introduced the IMO concept of SECAs and the associated stricter fuel standards. Under the Directive, the maximum sulphur content allowed in marine fuel was limited to a maximum of 1.5 percent for ships operating in the Baltic Sea as from 11 August 2006 and in the North Sea and the English Channel as from 11 August 2007. Even at the time of adoption, the EC recognised that these standards would not be enough to address the air pollution impacts from shipping.

The Commission therefore called for further action at the IMO to reduce emissions. The result of this was the adoption of an amended MARPOL Annex VI in October 2008, which lowers the maximum permissible sulphur content of marine fuels inside SECAs to no more than 1.0 percent from 1 July 2010 until 31 December 2014, after which the sulphur content should not exceed 0.1 percent from 1 January 2015 (EC, 2016b).

EU Member States therefore, had to ensure that ships operating in SECAs are using fuels with sulphur content of no more than 0.1 percent. The use of high sulphur content fuel is still possible to be used by ship operators but only if the appropriate exhaust gas cleaning systems are in place. For ships operating outside of SECAs, the sulphur content in fuel were limited to 3.5 percent from 18 June 2014 and not to exceed 0.5 percent as from 1 January 2020. These are the limits that are now in EU law as Directive 2012/33/EU.

Directive 2005/33/EC also saw some requirements that the EC has introduced that went beyond the IMO rules in recognition of the need to further improve air quality for the protection of human health beyond SECAs. The most important requirements being introduced are:

- The obligation for ships at berth or anchorage in EU ports to use fuels containing maximum 0.1 percent sulphur (effective 1 January 2010);
- The obligation for passenger ships on regular service to EU ports to use fuels containing a maximum sulphur content of 1.5 percent;
- The introduction of a possibility to test and use the emission abatement technologies.

The EU has also adopted the *Recommendation on the promotion of shore-side electricity for use by ships at berth in EU ports*. This allows ship operators to get electricity from the national grid while at berth in port, instead of ships using their own main engines to produce electricity. As such, this eliminates local air and noise emissions from ships' engines while at berths in port.

Although the Recommendation is not legally binding, ship operators are encouraged to consider the use of shore-side electricity as it benefits from eliminating ships emissions in EU ports, particularly in populated areas which suffers heavily from poor air quality. The EC promoted this measures by providing ship operators with information regarding practicalities, benefits and costs; by calling for harmonised international standards; and by highlighting the possible use of electricity tax reductions as an incentive to ship operators to use shore-side electricity (EC, 2016a).

Low Sulphur Fuel		Operating Areas	
Requirements	Outside ECAs	Inside ECAs	EU Ports
Starting Year 1 January	% Sulphur in Fuel	% Sulphur in Fuel	% Sulphur in Fuel
2010	4.5	1.0	0.1
2012	3.5	1.0	0.1
2014	3.5	1.0	0.1
2015	3.5	0.1	0.1
2020	0.5	0.1	0.1

Table 3-1 Low sulphur phase-in dates (highlighted areas indicate 0.5 percent sulphur and less)

Source: Author's own (based on data derived from IMO MARPOL Annex VI and European Commission Directive 2005/33/EC) 2019

3.4.3 EU greenhouse gas directives

In the 2011 White Paper on transport by the European Commission (EC), it was suggested that EU's CO2 emissions from maritime transport, excluding international shipping, should be cut by at least 40 percent, and if feasible by 50 percent of 2004 levels by 2050 (EC, 2011). As such, the EC set out a strategy in June 2013 to gradually incorporate maritime emissions into the EU's policy for reducing its domestic greenhouse gas emissions. According to Sopher and Mansell (2014), the strategy consisted of three consecutive steps:

1. Monitoring, reporting and verification (MRV) of CO2 emissions from large ships using EU ports;
2. Greenhouse gas reduction targets for the maritime transport sector; and
3. Further measures, including market-based measures in the medium to long term

The MRV regulation was adopted on 29 April 2015, which creates an EU-wide legal framework for the monitoring, reporting and verification of CO2 emissions from maritime transport. The MRV system has been estimated to cut CO2 emissions by up to two percent as compared to a 'business as usual' situation (EC, 2013a). The system also has added advantages of providing useful insights into the performance of individual ships, their associated operational costs and potential resale value.

3.4.4 Low sulphur fuel study

In order to help member states of the IMO determine if the new lower global cap on sulphur emissions from international shipping shall come into effect on 1 January 2020 or be deferred until 1 January 2025, the Organisation has commissioned a review of the availability of low sulphur fuel oil for use by ships. Under the terms of Annex VI Regulation 14 Rule 8, this review shall be completed by 2018. The reason for this feasibility study is to ensure the shipping industry will not be left in a lurch, with regards to insufficient availability of low sulphur fuel to meet global demands should the low SOx regulations be implemented.

The IMO hired a consortium of consultants lead by *CE Delft* to carry out the review, which were to include an assessment of the predicted demand for compliant fuel oil; and an assessment of the predicted supply of compliant fuel oil, based on the estimated ability of the refinery industry to supply the projected demand for marine fuel oil in meeting the global 0.5 percent sulphur limit required, starting in 2020 (IMO, 2015a). The report was completed ahead of the 2018 deadline in July 2016.

Prior to IMO's fuel assessment study on the technical feasibility of mass-producing 0.5 percent sulphur fuel oil in 2020, it is worth noting that ultra-low sulphur fuel oil (ULSFO) with a maximum sulphur content of 0.1 percent is already available and currently being used by ship-owners in ECA zones as a cheaper alternative to marine gas oil. According to Molloy (2016), ECA zone fuel oil typically trades at 20 USD (United States Dollar) per metric tonne or more discount as compared to marine gas oil (MGO) in Rotterdam. The use of ULSFO has significantly increased in Europe in 2016 after ship-owners started using it in 2015 to comply with MARPOL regulation which enforced a lower 0.1 percent sulphur cap on bunker fuel used in ECAs (Molloy, 2016). With the impending 2020 global low sulphur regulation, the demand for ULSFO is set to potentially increase even further. However, the capability of the world's refineries to meet the potential increase for the demand in distillate fuel will be difficult to predict, along with the price of bunker fuel oil at that point in time in 2020.

According to Molloy (2016), the experience of one ship charterer with regards to complying their ships with the 0.1 percent sulphur content in the North American ECA has been a constant challenge. This is due to the complete unavailability of the 0.1 percent intermediate fuel oil (IFO), the lack of MGO capacity on board, and the unreliability of low sulphur MGO supply in the charterer's trading range. Based on those challenges, the ship charterer concluded that there was nothing to suggest that bunker suppliers are prepared to cut sulphur content in fuel down to 0.5 percent as the heavy oil market has hardly responded at all to the 0.1

percent ECA regulation. Furthermore, the ship charterer believes that if bunker suppliers were faced with problems to produce 0.5 percent maximum sulphur fuel that also complies with ISO: 8217 standards, it is inevitable that tanks and engines would always need to be retrofitted for vessels to operate with MGO.

Based on the requirements by IMO to use low sulphur fuel to meet the 2020 global regulations, it could ultimately restrict ship-owners to use residual fuel such as heavy fuel oil (HFO) (without the use of sulphur abatement technology such as scrubbers). This could potentially result in shortages of distillate fuels over the next 12 to 15 years as refineries worldwide attempt to meet the market demand while maintaining the specifications associated with the required regulations (ABS, 2013). Despite this, the study by *CE Delft* concluded that enough distillates could be produced by 2020 to meet the increased marine demand. The review included a base-case scenario where there will be an increase of 8 percent in total energy use in the marine sector (CE Delft, 2016). According to **Table 3-2**, this means that the global marine fuel demand is set to increase to 320 million tonnes in 2020, from 300 million tonnes in 2012.

		Marine petroleum			Marine LNG		
	Non-marine	Base	High	Low	Base	High	Low
2012	3,692	292	292	292	8	8	8
2020	4,190	308	352	269	12	13	12

Table 3-2 Total fuel demand in 2020 (million tonnes per year)

Source: CE Delft 2016 p.41

According to Jasper Faber, an aviation and maritime specialist at *CE Delft*, the projected increase in distillates from the marine sector could be achieved from the ongoing secondary refining unit expansions which will take place until 2020 (Molloy, 2016). During his presentation on the preliminary results of the study at the Platts Rotterdam bunker conference in May 2016, he said:

> *“Hydrocracking and hydrotreatment capacity of refineries is projected to increase faster than global petroleum fuel demand, which potentially creates the capacity to produce compliant fuels”* (Molloy, 2016, p.2).

However, a rival study by consultants *Ensys* and *Navigistics* opposes this view (Ensys Energy, 2016). The consultants were not chosen by the IMO, but the study was nevertheless submitted to the Organisation by the International Petroleum Industry Environmental Conservation Association (IPIECA), an oil and gas industry group, and the Baltic and International Maritime Council (BIMCO), the largest ship-owner’s association, as a ‘second opinion’ to consider. According to the study, the refining capacity will not be sufficient in 2020 and it was estimated that an additional 60-75 percent sulphur plant capacity were required to be constructed by 2020 (Ensys Energy, 2016). The study by *CE Delft* meanwhile, does not see the sulphur plant capacity as an issue. The study has assumed that all units have enough sulphur plant capacity. Should this assumption not be accurate, the study states that refineries would need to expand the capacity of their sulphur plants in order to fulfil the 2020 demand (CE Delft, 2016).

There are significant differences between the two studies but one of the major differences is the assumption that the demand for low sulphur fuel would be filled by blends according to the *CE Delft* study. The study indicates that all the compliant 0.5 percent maximum sulphur fuel would be made up by blends of several refinery streams. This includes residue, cutter stock, unconverted hydrotreated oil, treated light distillate and also very small fractions of kerosene in some cases (CE Delft, 2016). On the other hand, the study by *Ensys* and *Navigistics* adopted a preliminary scenario instead where up to 90 percent of the demands for 0.5 percent maximum sulphur fuel is met by middle distillates while the other 10 percent by residual (Ensys Energy, 2016). The study also considers the minimum demand for distillates to be at 50 percent and shares the same view as the International Energy Agency (IEA) in which there would be a widespread shift to burning marine gas oil (MGO) as a first choice for the majority of shippers upon the introduction of the global cap in 2020 (Molloy, 2016). This was evident back in 2015 when the industry was faced with tighter environmental regulation and the majority of shippers decided to implement on the less capital intensive option and revert to burning MGO when sailing in ECAs (Molloy, 2016).

According to the report by the IEA, MGO is expected to take over the market share of bunker fuel (International Energy Agency [IEA], 2016). It estimates that in 2020 and 2021, the total oil-based marine fuel consumption in international shipping will be around 3.9 million barrels a day. Of this amount, 30 percent would be residual fuel oil and 70 percent gas oil. This represents a demand shift of 2 million barrels a day from residual fuel oil to gas oil.

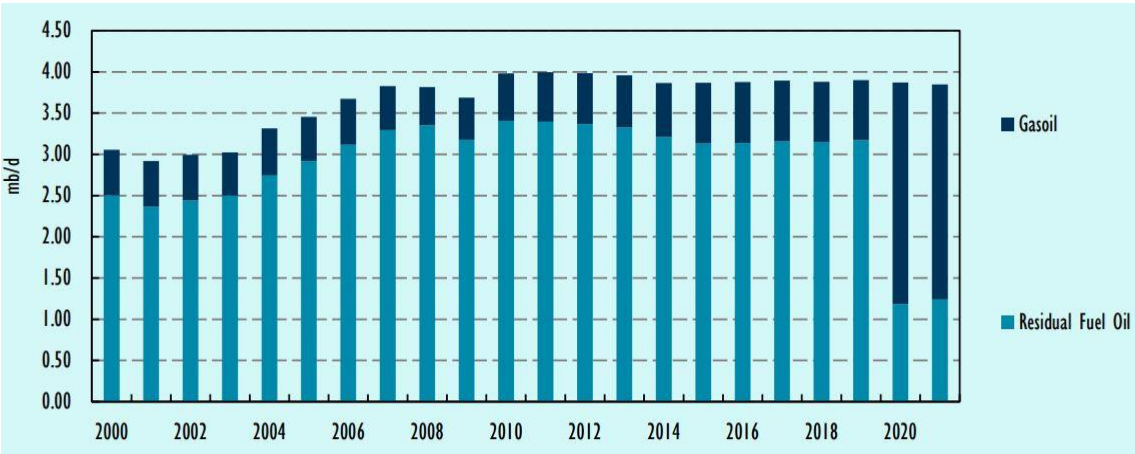


Figure 3-5 Oil-based marine fuel consumption (gas oil versus residual oil)

Source: IEA 2016 p.36

With the expected sheer scale increase in spending on compliant fuel, and the fact that most shipping sectors have remained in serious financial condition because of structural overcapacity, it comes as no surprise that some industry bodies were pushing for more time to deal with IMO's global low sulphur cap regulation. It has been estimated by Unni Einemo, media and communications manager at the International Bunker Industry Association (IBIA), that if the implementation date were to be pushed back to 2025, it would save the shipping industry somewhere between $30 billion and $50 billion a year in terms of savings from not switching between heavy fuel oil (HFO) to MGO (Molloy, 2016). Even though the IBIA, which represents both suppliers and end users of marine fuel, does not have an official position whether the IMO should implement the 0.5 percent global sulphur limit in 2020 or 2025, the association believes that there are still many unresolved issues ahead of the sudden drop to 0.5 percent from 2020. It is a drastic change for the industry and Einemo suggested that a phased introduction, even over six months would help alleviate the situation (Molloy, 2016).

Based on the final report by *CE Delft*, it was concluded that there would be enough distillates to be produced by 2020 to meet the increased marine demand. As such, the IMO, ending years of uncertainty announced on October 27, 2016 that it was going ahead with a global sulphur cap of 0.5 percent on marine fuels starting from January 1, 2020. This is despite of the findings based on the study by *Ensys* and *Navigistics* which highlights potential problems for refineries to meet the demands.

3.5 Ballast water management convention

The International Convention for the Control and Management of Ships' Ballast water and Sediments was adopted by the IMO in 2004 and entered into force on 8 September 2017 (IMO, 2017; Rahman, 2017). The Convention was established to prevent the spread of potentially harmful aquatic organisms and pathogens in ships' ballast water.

According to Hill *et al.* (2017), the *"uptake and discharge of ballast water between isolated marine habitats allows for organisms, normally separated by environmental or geographical barriers, to be transferred to a naïve location wherein the species does not naturally occur"* (p.3). The deballasting process may result in the establishment of colonies of harmful species and pathogens in the waters of port states. This can seriously disrupt the existing ecological balance and cause significant economic and social impacts, which have the potential to destabilise small economies (Hill *et al.*, 2017; Rahman, 2017). Furthermore, the spread of pathogens globally has resulted in local outbreaks of cholera, a potentially fatal disease. This was evident in 1991 and 1992, when the bacterium was found in the ballast water of five cargo ships docked in ports of the Gulf of Mexico (McCarthy and Khambaty, 1994). It caused more than 1.2 million cases of cholera and resulted in the deaths of more than 12,000 people in Latin America (Takahashi *et al.*, 2008).

As such, the Ballast Water Management Convention (BWM Convention) stipulates that all ships in international traffic must manage their ballast water so that aquatic organisms and pathogens are removed or rendered harmless before that water is released into a new location (IMO, 2019a). Management includes preparing and following an approved ballast water management plan, keeping a record of ballast water operations, and performing ballast water management procedures to a given standard as defined under the Convention (Hill *et al.*, 2017; IMO, 2017; Rahman, 2017). In practice, this will eventually require that all vessels must be fitted with an IMO-approved ballast water treatment system, to ensure that the system does not pose unreasonable risks to the environment, human health, property or resources.

3.5.1 Ballast water management standards

While ballast water treatment system is being phased in, the IMO has established two ballast water management standards for ships. The D-1 standard applies to ships without a treatment system fitted onboard, while the D-2 standard applies to ships fitted with a treatment system.

The D-1 standard requires ships to exchange their ballast water and be capable of achieving at least a 95 percent volumetric exchange of water using one of the IMO's recognised forms of exchange (Rahman, 2017). Such exchanges are to be undertaken in open seas and away from coastal waters. Essentially, ships must exchange their ballast water at least 200 nautical miles from the nearest land and in water of at least 200 metres deep (IMO, 2017; Rahman, 2017). In cases where ships are unable to perform ballast water exchange in accordance with the above, it is to be conducted at least 50 nautical miles from the land at a depth of 200 metres (Maritime and Coastguard Agency, 2018). This is to ensure most coastal organisms are killed as they are unable to survive the harsh ocean environment. Ships are then less likely to introduce potentially harmful species when discharging ballast water. This is not a long-term solution because of the impact on ship's stability during exchange. This was evident in July 2006, when merchant vessel *Cougar Ace*, a 55, 328 gross tonnage car carrier, *"developed a list of up to 85 degrees during ballast operation"* (p.100) and nearly capsized off the coast of Alaska (Donner, 2010).

D-2 on the other hand, is a performance standard which specifies the maximum amount of viable organisms allowed to be discharged, including specified indicator microbes harmful to human health (IMO, 2017; Maritime and Coastguard Agency, 2018). This involves installing special equipment to treat the ballast water. That equipment did not exist in an approved form at the time the convention was adopted.

From the implementation date of the BWM Convention on 8 September 2017, all ships had to conform to at least the D-1 standard; and all new ships, to the D-2 standard. However, existing ships will eventually have to comply to D-2 standard, as ballast water exchange will be phased out as an acceptable method to comply with the Convention. For most ships, this involves retrofitting their ballast water systems to include approved treatment mechanisms to sterilise ballast prior to discharge. The implementation timetable for D-2 standard on existing ships is linked to the ship's International Oil Pollution Prevention Certificate (IOPPC) renewal survey (Hill *et al.*, 2017; IMO, 2017). Based on the IOPPC renewal survey, existing ships should meet the D-2 standard no later than 8 September 2024.

3.5.2 Delayed implementation of ballast water convention

The BWM Convention took 13 years after its original adoption date to be entered into force worldwide. The Convention was quoted by the International Chamber of Shipping (ICS) to be *"one of the most complex and controversial pieces of technical regulation ever adopted by* [the] *IMO"* (International Chamber of Shipping [ICS], 2018, p.1).

The key reason for the delay was due to technical difficulties with the equipment needed to meet the requirements of the Convention. When the Convention was adopted back in 2004, the *"technology required for ships to treat millions of gallons of ballast water simply did not exist outside of a laboratory"* (ICS, 2018, p.1). Ship-owners were also reluctant to install the expensive and unproven systems required under the Convention, as the type-approval standards initially adopted by the IMO for the treatment systems were insufficiently robust. This resulted in most major Flag States to delay ratifying the Convention until the issues were resolved (Donner, 2010; IMO, 2017). As such, entry into force of the Convention was delayed as there were insufficient ratifications by Member States.

Under the BWM Convention, it was stipulated that the Convention would be enforced 12 months after ratification by a minimum of 30 Member States. This represents 35 percent of the world's merchant shipping tonnage. The criteria were eventually met on 8 September 2016, after key issues regarding the Convention had been addressed and agreed by Member States (IMO, 2017). The BWM Convention subsequently entered into force on 8 September 2017.

3.6 Regulation enforcement issues

Regulations enforced by regulatory bodies such as the IMO and the EU, whilst necessary, pose a significant cost and compliance challenges to the shipping industry. If not properly enforced, the regulations will be ineffective at reducing pollution and the related health impact of pollution from shipping, thereby making the regulations meaningless. In scenario where the regulations are robustly implemented, it will make compliance the norm and therefore, competition is not distorted. But in cases where enforcement is weak, companies may be more inclined to cut corners on compliance.

Global low sulphur regulation enforcement

For the 2020 global low sulphur regulation, there is currently no evidence to suggest on the level of enforcement to be taken by Flag and Port States within the EU. This has led to some of the industry's ship-owners and operators, who shares a common interest in the robust and transparent enforcement of maritime regulations, to come together to form the ‘Trident Alliance’ group.

Members of the alliance include some of the world’s largest container shipping companies such as *Maersk Line* and *Hapag-Lloyd*, as well as bulk carriers including *J. Lauritzen*, reefer operators like *Seatrade* and ferry companies such as *Stena Line*. The alliance also partners with other stakeholder groups who shares the same interest in robust enforcement by working together on initiatives that support this objective. For these companies that is committed in complying with the regulations, effective enforcement of the sulphur cap is the only way to ensure a level playing field with other companies that may not be as keen to comply, and through using cheaper, non-compliant fuel, undercut them on rates (Molloy, 2016).

Dea Frochhammer, senior business development manager at *Maersk Oil Trading*, spoked out on the need for a strict enforcement of the global sulphur cap on shipping at *Platts Rotterdam bunker conference* in May 2016 (Molloy, 2016). She also voiced out on *Maersk’s* concerned that not all companies would comply with the global low sulphur regulation due to an unclear legal framework, lack of dissuasive sanctions, insufficient detection methods and limited resources which have all created a loophole for risk-free non-compliance.

<u>Emission Control Area (ECA) enforcement</u>

The 2015 ECA zone requirements also lacks effective enforcement. According to Dea Frochhammer, non-compliance rates in port inspections conducted were three percent in the Baltic Sea and nine percent in the North Sea (Molloy, 2016). However, only 30 percent of violations were sanctioned; deemed as unacceptable. Even if dishonest ship-owners were to be prosecuted, they would still benefit and would not be severely affected, considering some fines were as low as 1,500 USD. In comparison, the fines were not as significant as the amount these ship-owners stood to save per trip, per ship using non-compliant fuel in the current ECA zones, which was in excess of 100,000 USD (Molloy, 2016). As such, ship-owners would still be undeterred by the regulations as detention rates were low and there were very few cases of legal action for non-compliance.

Country	Maximum financial penalty
Belgium	Eur 6 million
Canada	CAD 25,000
Denmark	No maximum
Finland	Eur 800,000
France	Eur 200,000
Germany	Eur 22,000
Latvia	Eur 2,900
Lithuania	Eur 14,481
Netherlands	Eur 81,000 + gains
Norway	No maximum
Sweden	SEK 10 million
UK	GBP 3 million
USA	USD 25,000/d

Table 3-3 Penalties for non-compliance to SOx regulations in selected countries within SECAs

Source: Molloy 2016 p.9

The responsibility for enforcing the regulation lies on individual Parties to MARPOL itself such as Flag and Port states. The IMO does not establish fines or sanctions for Member States to implement as it is up to individual State Parties to the convention to set it up. In addition, due to the absence of a global organisation responsible for enforcement of emissions regulations in international waters, any breach in the global sulphur cap could result in disputes about jurisdictional authority (Molloy, 2016). However, this situation might not prevail as all the key shipping organisations such as the International Chamber of shipping had indicated that all their members would comply with the new regulations.

The penalties being imposed by Flag or Port States on non-compliance ships varies significantly in various ECA zones. In the North America, the penalties imposed on vessels are tougher than anywhere else. The United States Coast Guard has the power to seize vessels that are in breach of the sulphur regulations and the owners would be subjected to heavy fine. In contrary, the enforcement in the northwest European ECA zone is less clear as each EU state is responsible for policing its own territorial waters. Therefore, in order to have a successful enforcement on a global scale with regards to the global sulphur regulation, it is crucial to learn from and upscale the monitoring of compliance in ECA zones.

The way that Flag and Port States are currently carrying out enforcement is done by in-port verification of bunker fuel sulphur levels, using airplanes and drones to monitor ship's smokestack emissions at sea, and using electronic 'sniffers' (nose sensors) on bridges. In the open seas however, it would be difficult for Flag or Port States to effectively carry out enforcement as there is currently no failsafe detection measure that could be installed onboard without being tampered with by crews. The industry needs a black box on ships, similar to an airplane, to measure what the ship is emitting (Molloy, 2016).

<u>BWM Convention enforcement</u>

Enforcement of the BWM Convention consists of a four-stage approach:

- Initial inspection
- More detailed inspection
- Indicative sampling
- Compliance sampling

The process starts with an initial inspection which consists of three elements: document control, human element and a general examination. If there are clear grounds that the initial inspection was unsatisfactory, a more detailed inspection will be carried out. This involves comparing the operation of the system to the ballast water management plan and the indicators as defined within the type approval certificate. When there are still doubts, sampling of the ballast water may be carried out (Hill *et al.*, 2017).

In terms of carrying out enforcement for BWM Convention, the responsibility lies under Port State Control (IMO, 2014a). Enforcement is carried out according to the Guidelines for Port State Control under the BWM Convention, which is stipulated under Resolution MEPC.252(67) of the IMO, and the relevant Paris Memorandum of Understanding instruction (Inspectie Leefomgeving en Transport [ILT], 2017).

To discourage any violations to the BWM Convention requirements, Parties to the Convention should transpose the Convention into their legal framework and establish adequate sanctions (Hill *et al.*, 2017). In situations where a ship has violated the BWM Convention, Port State control officers may *"take steps to warn, detain or exclude the ship or grant such a permission to leave to discharge ballast water elsewhere or seek repairs"* (IMO, 2014a, p.9). Wherever such violation occurs, sanctions are established under the Flag State of the ship concerned. Sanctions are also available to the Port State in accordance with its own law (IMO, 2004). This would normally be sanctions.

Although two years has elapsed since the BWM Convention came into force on 8 September 2017, countries within the EU that have ratified the BWM Convention have yet to stipulate penalties for non-compliance. EU countries such as the United kingdom, Italy and Hungary have also yet to ratify the Convention as of April 2019 (ABS, 2019). This may indicate that the BWM Convention within the EU is not properly implemented. Unclear enforcement level and penalties for non-compliance to the BWM Convention may indicate similar issues with regards to the effective implementation of IMO's 2020 global sulphur regulation. It is therefore crucial for Flag and Port States to take necessary steps that will ensure robust enforcement of the sulphur regulation when it comes into force on 1 January 2020.

3.6.1 Linked roles of CSR and enforcement of regulation

As covered in **Chapter 2.3**, CSR is a multi-quantifiable tool used to represent responsible business activities towards all concerned stakeholders. The dimensions of CSR are economic responsibility, ethical responsibility, legal responsibility and green ethical considerations. These are required for a sustainable company, with green ethical consideration at its core.

In terms of legal responsibility, companies are required to comply with laws and regulations and are playing by the 'rules of the game' (Lantos, 2001; Jamali and Mirshak, 2007). Some companies may even go beyond full compliance in anticipation of future regulations (Reinhardt *et al.*, 2008). However, McBarnet (2009) and Vives (2007) argued that regulation is not often as effective as might be expected in changing business behaviour.

Although there are risks of fines for non-compliance (Baden, 2017), companies may still not conform to requirements. This is partly due to compromise in the substance of regulation and partly due to government failure to adequately enforce existing regulations; resulting in the continued absence of socially responsible behaviours in companies (McBarnet, 2009; Belal and Cooper, 2011).

If there is no realistic threat of regulatory enforcement, companies will not *"necessarily act in a socially responsible manner* […], *but they are predisposed to comply once regulations are on the books and are being enforced"* (Maltby, 1997, p.90).

The penalties for non-compliance may also be so weak that companies treat it as just another business cost (McBarnet, 2009). According to Vives (2007), some companies adopt a cost-benefit approach to compliance with regulations. This involves evaluating the probability of getting caught, the amount of the fine if caught and the ways to evade payment of the fine. These factors are all balanced against the 'benefits' of non-compliance.

In addition, 'creative compliance' contributes to the ineffective implementation of regulation. Companies are extremely capable at finding 'arguably legal' ways to get around regulatory control to *"simultaneously escape legal control and any threat of penalty for doing so"* (McBarnet, 2009, p.6). Such behaviour suggests the need for stronger legal enforcement to secure companies' responsible compliance with regulation.

Vives (2007) suggested enforcement can be enhanced with more resources and more powers, and strong enforcement makes it fairer and establishes a level playing field for companies. Governments can make changes to the regulation, to make 'creative compliance' more challenging for companies. It is important to enforce regulations in ways that deter and correct irresponsible behaviour by companies.

Theoretically, based on reviewed literature, there are linked roles between CSR, regulations and enforcement of regulations. These linked roles however, may or may not result in innovation by companies.

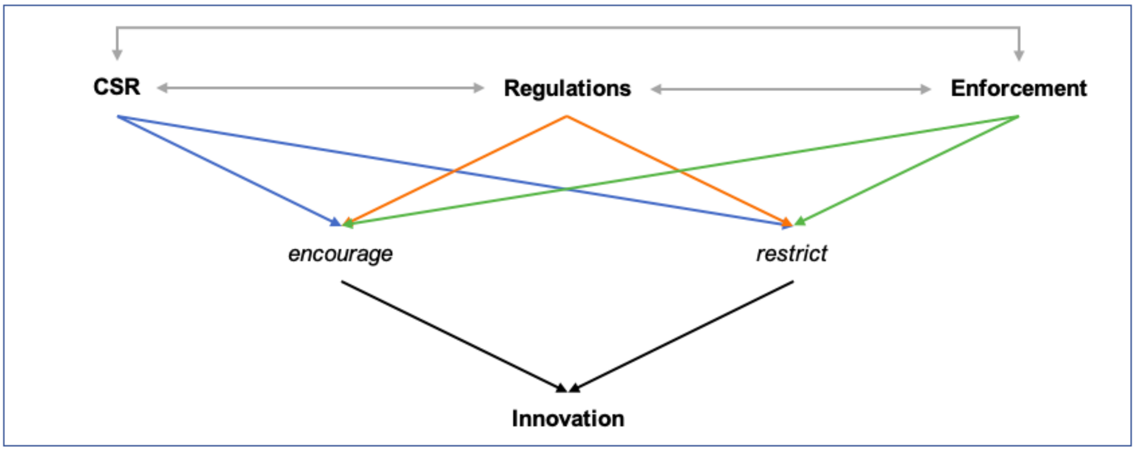


Figure 3-6 Linked roles of CSR, regulations and enforcement of regulations

Source: Author's own 2019

As covered in **Chapter 2.4**, companies' CSR was claimed to be a catalyst for innovation as coping with environmental regulations requires the development of new technologies. However, it may not always result in new innovations as companies may lack the resources needed for investment, there may be insufficient demand for the innovation or companies are affected by other factors restricting their innovation activities (see **Figure 2-4**). In other words, although the roles of CSR and regulations are linked, it is dependent on the company whether it leads to new innovations being introduced or otherwise.

As covered earlier in this section, the level of enforcement has an impact on the effective implementation of regulation. In theory, if the level of enforcement is low, companies may cut corners on compliance; resulting in an unfair advantage. Low enforcement levels also mean that demand for new innovative products is weak; thus, affecting companies' innovation activities. As such, robust implementation of regulations is allegedly, more likely to encourage companies to partake in innovation activities (Maltby, 1997).

3.7 Analysis of air quality regulation

As covered in earlier sections, there are several types of emissions generated by ships. Through a chemical reaction in the air, some of these pollutants such as sulphur dioxide (SO2) and the mono-nitrogen oxides (nitric oxide and nitrogen dioxide; commonly referred to as NOx), are converted into fine particles: sulphate and nitrate aerosols (Molloy, 2016). In addition to black carbon, which are directly emitted from ships, these secondary particles are a major source of air pollution that have an adverse impact on human health. The fine airborne particles are linked to premature death as the particles get into the lungs and are small enough to enter the blood. From there, these particles can trigger inflammations; subsequently leading to heart and lung failures (Molloy, 2016). Furthermore, these pollutants also causes acid rain that can have harmful effects on plants, aquatic animals and infrastructure (Molloy, 2016).

It was reported that air pollution from international shipping accounts for approximately 50,000 premature deaths per year in Europe; amounting to more than €58 billion annual cost to society (Brandt *et al.*, 2011). However, Transport and Environment (2018), Europe's leading non-governmental organisation campaigning for greener transport policies, estimates that approximately 26,000 lives in the EU can be saved from 2020. This is possible from the implementation of the global 0.5 percent sulphur limit for marine fuels coming into force in 2020. This is evidence that human health is one of the rationales for enforcing a global lower sulphur cap.

3.7.1 Types of emissions generated by ships

Sulphur oxide

Sulphur oxide (SOx) refers to diverse types of sulphur and oxygen containing compounds and the most common type is SO2. SO2 is emitted when fuels containing sulphur are combusted. It is a pollutant that contributes to acid deposition (commonly known as acid rain), which occurs when it reacts in the atmosphere with water, oxygen, and oxidants to form various acidic compounds (Ionada, 2016). Acid rain can lead to potential changes in soil and water quality (Tay, 2011; EC, 2016b). The subsequent impacts of acid rain can be significant, including having adverse effects on aquatic ecosystems in rivers and lakes and damage to forests, crops and other vegetation (European Maritime Safety Agency [EMSA], 2017b).

SO2 also contributes to the formation of particulate aerosols (commonly known as particulate matter) in the atmosphere. Particulate matter (PM) is an important air pollutant due to its adverse impact it has on human health. It causes respiratory and cardiovascular diseases and also reduces life expectancy in the EU by up to two years (EC, 2016b; EMSA, 2017b). The effects of PM are further explained later in this section.

Nitrogen oxide

Nitrogen oxide (NOx) refers to a group of gases composed of nitrogen and oxygen containing compounds. Two of the most common NOx are nitric oxide (NO) and nitrogen dioxide (NO2). NOx is produced during the process of high temperature combustion in motor engines, where an endothermic reaction (in which the system absorbs energy from its surroundings) produces the various oxides of nitrogen (Tay, 2011). When these chemical gases are released into the atmosphere, it may react with water, oxygen and other substances to form nitric acid, which causes acid rain to occur (Tay, 2011; Ionada, 2016). Acid rain has many ecological effects but its impact on lakes, streams, wetlands and other aquatic environments are more significant.

NOx also reacts with ammonia to form nitric acid vapour and related particles that can penetrate deeply into sensitive lung tissue and causing damage (EMSA, 2017a). In extreme cases, it can further lead to premature death. NOx can also form ozone (O3) after reacting with volatile organic compounds in the presence of sunlight. O3 can have adverse effects on human health, such as damaging lung tissue and reducing lung function in mostly susceptible populations (children, elderly and asthmatics) (EMSA, 2017a). Furthermore, as O3 can be transported by wind currents, its negative impacts can take place in locations far from the original source.

Carbon dioxide

Greenhouse gas (GHG) is a gas in an atmosphere that absorbs and emits radiation within the thermal infrared range. A major component of the GHG is carbon dioxide (CO2) which is a by-product from the combustion of fossil fuels and other natural fuels such as wood, coal, oil and gasoline. An increase of anthropogenic CO2 to the atmosphere will have consequential contribution to the GHG effect and global warming (EMSA, 2017a).

Other primary GHG include water vapour, methane, nitrous oxide and ozone. These GHS are what causes climate change; amongst other direct effects of global temperature increase. Furthermore, the continued build-up of these gases could potentially have a harmful effect on the ecosystem, biodiversity and livelihoods of people globally (Ionada, 2016).

Particulate matter

Particulate matter (PM) is a type of air pollutant consisting of a mixture of solid and liquid particles suspended in the air. Common chemical constituents of PM include: sulphates; nitrates; ammonium; other inorganic ions; organic and elemental carbon; particle-bound water and polycyclic aromatic hydrocarbons (World Health Organisation, 2013). PM are emitted directly into the air by ships during engines combustion of both diesel and petrol.

PM include inhalable particles that are small enough to penetrate the thoracic region of the respiratory system. Its health effects are well documented. According to the World Health Organisation (2013), PM in humans can cause: respiratory and cardiovascular morbidity; premature mortality; changes in lung function and increased respiratory symptoms; changes to lung tissues and structure and alter respiratory defence mechanisms. Apart from human heath, PM also influences the environment; causing visibility impairment (haze) and materials damage (Environmental Protection Agency [EPA], 2018).

3.7.2 Synthesising air quality regulation and policy of the EU and IMO in relation to atmospheric emissions from shipping

The process of synthesis is a written discussion that draws from one or more sources, where relationships among different sources are inferred. There are two types of syntheses: explanatory and argument (Carter, 2017).

Explanatory synthesis involves dividing a subject into its component parts and presenting it in a clear and orderly fashion. The aim of this synthesis is to help the researcher understand a topic; it does not go much beyond what is understandable from attentive reading of the sources. It is merely a form of presenting the facts in a reasonably objective manner, rather than arguing on an issue. On the other hand, argument synthesis is a type of synthesis which involves presenting the researcher’s own point of view. The arguments are supported by relevant facts that were drawn up from the sources used and presented in a logical manner.

For this research, the explanatory synthesis is employed to make a basic and logical table showing the type of regulation or policy that regulates each type of emissions. The data were derived from secondary sources using conference proceedings from the IMO and Directives from the EU. **Table 3-4** therefore provides a comprehensive overview of the different regulations regulating different types of emissions and their respective implementation dates. This table allows its reader to understand all the standards that needs to be met, when looking at possible measures or solutions to adopt to comply with the global sulphur regulation. These possible measures and solutions are examined in the next chapter.

	SOx	NOx	CO2	PM
EU	Basic regulation for regulating sulphur emissions from ships was Directive 1999/32/EC Amended by Directive 2005/33/EC which designated the Baltic Sea, the North Sea and the English Channel as sulphur emission control areas (SECAs). Maximum sulphur content used by ships operating in these sea areas are limited to 1.5 percent Directive 1999/32/EC was further amended in October 2008 (IMO's MARPOL Annex VI was adopted) to meet the standards developed by the IMO. These limits are now in EU law as Directive 2012/33/EU From 1 JAN 2015, EU Member States must ensure that ships in the Baltic, the North Sea and the English Channel are using fuels with a sulphur content of no more than 0.10 percent Higher sulphur contents are possible only with appropriate exhaust cleaning systems in place Under the amended Directive 1999/32/EC, passenger ships on	Directive 1999/32/EC (amended by Directive 2005/33/EC and subsequently by Directive 2012/22/EU) does not contain provisions to regulate ship emissions of NOx Besides the reference to NOx emissions from ships in the Commission's Communication on a "Strategy to reduce atmospheric emissions from seagoing ships (2002)" and the "Thematic Strategy on Air Pollution (2002)" there is currently no binding EU legislation on NOx emissions reductions from ships. The latter Communication stated that NOx emissions need to decrease by 60 percent to avoid 47 percent reduction in loss of life expectancy because of exposure to particular matter, and 10 percent reduction in acute mortalities from exposure to ozone In April 2014, the vote at the European parliament failed to include nitrogen oxides as part of ship emissions' monitoring requirements. The reason was that it would result in impractical monitoring issues in the proposed EU Regulation as continuous NOx	The Commissions' 2011 White Paper on transport suggests that EU's CO2 emissions from maritime transport should be cut by at least 40 percent from 2005 levels by 2050, and if feasible, by 50 percent. International shipping however, is not covered by the EU's current emissions reduction targets In JUN 2013, the Commission set out a strategy for progressively integrating maritime emissions into the EU's policy for reducing its domestic greenhouse gas emissions. The strategy consists of 3 consecutive steps: 1) monitoring, reporting and verification of CO2 emissions from large ships using EU ports; 2) greenhouse gas reduction targets for the maritime transport sector; and 3) further measures, including market-based measures, in the medium to long term MRV Regulation was adopted on 29 APR 2015, which requires large ships over 5,000GT calling EU ports from 1 JAN 2018 to collect and publish verified annual data on	PM_{10} shall mean particulate matter which passes through a size-selective inlet with a 50 percent efficiency cut-off at 10μm aerodynamic diameter $PM_{2.5}$ shall mean particulate matter which passes through a size-selective inlet with a 50 percent efficiency cut-off at 2.5μm aerodynamic diameter Limit values for PM_{10}: In a 24-hour limit value for the protection of human health, 50$\mu g/m^3$ of PM_{10} not to be exceeded more than 35 times a calendar year. Limit value entered force on 1 January 2005* For the annual limit value for the protection of human health, 40$\mu g/m^3$ of PM_{10}. Limit value entered force on 1 January 2005* *Under Directive 2008/50/EU, Member States could apply for an extension until three years after the date of entry into force of the new Directive in a specific zone. In such cases within the time extension period the limit value applies at the

EU	regular service are also subjected to new sulphur limits from 1 January 2015 and until 1 January 2020: **Inside EU SECA** 0.10 percent **Outside EU SECA** 1.50 percent (0.5 percent limit applies after 1 January 2020)	monitoring is much more complex and technologically challenging than CO_2 monitoring	CO_2 emissions and other relevant information Companies operating large ships calling at EU ports, irrespective of where the ships are registered, will have to: - monitor and annually report the verified amount of CO_2 emitted on journeys to, from and between EU ports and when in EU ports; - monitor and annually report additional parameters, such as distance, time at sea and cargo carried to determine ships' average energy efficiency; and - submit to the Commission an emission report containing externally verified annual aggregated data which will then be made publicly available When visiting EU ports, ships must carry a document of compliance issued by an accredited MRV verifier indicating that the ship is in compliance with its MRV obligations for its activities during the year. This document might be subjected to inspections by Member State authorities	level of the limit value + maximum margin of tolerance <u>Limit values for $PM_{2.5}$:</u> For the annual limit value for the protection of human health, 25μg/m^3 of $PM_{2.5}$. Limit value entered force on 1 January 2015 Directive 2008/50/EC introduced additional $PM_{2.5}$ objectives targeting the exposure of the population to fine particles. These objectives are set at national level and based on the average exposure indicator The $PM_{2.5}$ exposure reduction target (reduction to be attained where possible in 2020, determined based on the value of exposure indicator in 2010) is to reach 18μg/m^3

	SOx	NOx	CO2	PM
IMO	Regulated by MARPOL Annex VI (first adopted in 1997, entered force on 19 MAY 2005) MARPOL Annex VI revised in 2005 with the aim of strengthening emission limits based on technological improvements and implementation experience Amendments were adopted in October 2008 and entered into force on 1 JUL 2010 Main changes to Sox emissions: **Outside ECA** 4.50 percent prior to 1 JAN 2012 3.50 percent on and after 1 JAN 2012 0.50 percent on and after 1 JAN 2020 **Inside ECA:** 1.50 percent prior to 1 JUL 2010 1.00 percent on and after 1 JUL 2010 0.1 percent on and after 1 JAN 2015	Progressive reductions in NOx emissions from marine diesel engines installed on ships: Tier I: Applies to engines installed on or after 1 JAN 1990 to 1 JAN 2000 Tier II: Applies to engines installed on or after 1 JAN 2011 Tier III: Applies to engines installed on or after 1 JAN 2016 operating in ECAs (more stringent emission limit) NOx Technical Code 2008: regulation of existing (pre-2000) engines provisions for a direct measurement and monitoring method, a certification procedure for existing engines and test cycles to be applied to Tier II and Tier III engines	In 2011, the IMO adopted the Energy Efficiency Design Index (EEDI), which sets compulsory energy efficiency standards for new ships; and, the Ship Energy Efficiency Management Plan (SEEMP), a management tool for shipowners The adopted measures add to MARPOL Annex VI a new Chapter 4 entitled “Regulations on energy efficiency for ships”, making mandatory the EEDI for new ships and the SEEMP for all ships The regulations entered into force through the tacit acceptance procedure on 1 JAN 2013 and apply to all ships over 400GT and above	With regards to PM, there is no specific limit on its emissions under the IMO. However, the sulphur portion of PM formation is still regulated by the IMO through the fuel sulphur content requirements of Regulation 14 to Annex VI

Table 3-4 EU and IMO’s air quality regulation in relation to atmospheric emissions

3.8 Summary

This chapter has identified and selected the IMO and the EU as institutions for this research. This is due to the IMO being the regulatory body that sponsors international conventions related to pollutions and implements regulatory and market-based measures for the global shipping industry; while the EU represents the governing body responsible for regional matters related to shipping activities, which is in line with the focus of this research being on the EU.

This chapter has also examined the air pollution regulations from which is research is based, in addition to the BWM Convention which is used as a comparator to the air pollution regulation. Having understand the type of air emissions generated by ships and the impact it has on the environment and human health, the next chapter looks at solutions available for ship-owners to implement to comply with the stricter air regulation.

CHAPTER 4 MARINE EQUIPMENT SECTOR AND SOLUTIONS TO COMPLY WITH SULPHUR REGULATION

4.1 Introduction

This chapter first examines the marine equipment sector in the European Union (EU) before examining regulation as a driver of innovation based on theoretical foundations covered in **Chapter 2**. The link between regulation and green product innovation in the marine equipment sector were also examined.

The next part of this chapter explores the solutions and measures ship-owners can implement on their ships to comply with the 2020 global low sulphur regulation. This include different types of alternative fuels ship-owners can switch to, and different technological products available to ship-owners to implement. The advantages and disadvantages to each measure were also discussed. Barriers to implementation of technological products to meet the 2020 low sulphur regulation is also examined before a summary of this chapter is presented.

4.2 Marine equipment sector

Marine equipment refers to all products and services that are supplied for the building, conversion, maintenance of ships (seagoing and inland) and maritime structures (EMEC, 2010). This also include technical services in the field of engineering, installation and commissioning, and ship maintenance (including repair).

The marine equipment sector in the EU has outstanding ability to design, manufacture and build a range of high-tech vessels and maritime structures which meet the most stringent safety and technical requirements (EC, 2013b). They are world leaders in the development and manufacturing of propulsion, cargo handling, communication, automation and environmental systems (EMEC, 2006, 2010; EC, 2013b). This has enabled the EU marine equipment sector to engage in global trade, exploit resources and defend its strategic interests.

The European marine equipment sector is a high value added sector that competes in a global market where a leading position cannot be based on price alone (EMEC, 2006, 2010). It is made up of a large number of small and medium-sized enterprises, estimated to be between 5,000 and 7,000 companies in Europe (EC, 2012a). The sector maintains its competitiveness by offering innovative and reliable high quality products and increases the prosperity of the whole industry by driving the involvement of companies in all EU programs (EMEC, 2006, 2010). Essentially, research, innovation and development are crucial for success.

The European Marine Equipment Council merged with the Community of European Shipyards Associations (CESA) on 1 June 2012 into a new association called SEA Europe (Eason, 2012; Balance Technology Consulting, 2014). SEA Europe, the European Shipyards' and Maritime Equipment Association now represents the European maritime technology industry. The association supports and promotes European business enterprises which are involved in the building, construction, maintenance and repair of all types of ships and other relevant maritime structures, including the complete supply chain of systems, equipment and services (SEA Europe, 2013).

The association is focused on building and manufacturing advanced products to transform today's global maritime landscape to be competitive, strategic and sustainable. For a sustainable future, this will be based on safe, efficient and innovative maritime technologies and structures (SEA Europe, 2014). In order to meet its focus, SEA Europe has defined a number of missions to guide the strategic direction of the association, such as (SEA Europe, 2014):

- To promote the design, construction, maintenance, refit and modernisation of excellent safe and environmentally sound ships, maritime structures, products and services by using state-of-the art technologies, irrespective of their flag or area of operation.
- To follow the work of IMO and other regulatory bodies.
- To promote and facilitate research, development and innovation in the sector including the promotion of relevant projects and the dissemination of results among its members.

Therefore, advanced technologies, continuous investment in research, development and innovation of products and production methods are the key drivers to enhance the competitiveness of the European maritime technology industries (EC, 2003). Furthermore, the marine equipment industry is part of the blue economy in the EU, which is made up of individual sectors that are interdependent and rely on common skills and shared infrastructure (EU, 2012).

According to a report by the European Commission, growth in the blue sector is able contribute to EU's competitiveness in international markets, resource efficiency, job creation and new source of growth whilst safeguarding biodiversity and protecting the marine environment (EU, 2012). As the blue economy needs to be sustainable and environmentally friendly, efforts are required to reduce the negative environmental impacts of maritime activities such as the emissions of pollutants and the discharge of noxious substances.

In order to support sustainable growth and address the societal challenges Europe faces, an integrated approach which sees stronger involvement of the user industries, trade unions, non-governmental organisations and European national and regional actors is required (EC, 2013b). The marine equipment sector believes that a public private partnership (PPP) with clearly defined objectives and a long-term commitment from the industry together with EU, national and regional institutions, is an effective tool to meet international regulations that are particularly challenging for the marine equipment sector (EC, 2013b). This is due to the ambitious environmental and safety targets which requires coordinated effort and huge investment for breakthrough solution (EC, 2013b).

In a report by the European Commission on *LeaderSHIP 2020*, one of the themes of focus for a strong, sustainable and competitive European maritime industry in 2020 is research, development and innovation (RDI) (EC, 2013b). Efforts in RDI are needed to foster innovation in products and also for process and non-technological innovation which are key factors for the competitiveness of the sector (EC, 2013b). The EC is promoting innovation as it is needed to strengthen the competitive position of European equipment manufacturers, ship-owners and ship-operators (EC, 2012b).

One of EU's programmes for marine and maritime research and innovation includes the future *Horizon 2020* programme, which targets research and innovation on matters pertaining to green transport and climate action (EU, 2012). For the maritime industry to be at the forefront in terms of footprint and emissions per ton-kilometre, it is crucial for innovation to take place within the marine equipment industry to achieve this. The road transport sector is already leading over maritime in terms of development of cleaner engines (EC, 2013b).

4.2.1 Regulation as a driver to innovation

As covered earlier in **Chapter 2.4.2**, there are several literatures that discussed how environmental regulation encourages innovations within companies

(Lanjouw and Mody, 1996; Lohmuller, 2004; Lanoie *et al.*, 2011; Horbach *et al.*, 2012). However, when it came to verify the accuracy of the statement concerning the innovation inducement impact of environmental regulations, examples such as the marine scrubber systems or ballast water management systems are hardly reviewed. The lack of empirical studies on such product innovations, made it challenging to establish whether regulation encourages innovation in the marine equipment sector.

There are contrasting views with regards to whether stricter regulation would in fact, promote competitiveness amongst firms by the introduction of innovation (Makkonen and Repka, 2016). In other words, growing environmental regulation and concerns could drive the need to develop and apply innovative alternative power and propulsion technology for ships. Furthermore, there were also no evidence to suggest that the BWM Convention encourages innovation in the marine equipment sector. Matters pertaining to environmental protection were traditionally viewed by economists and managers to have additional costs imposed on firms, which could possibly diminish their global competitiveness (Ambec *et al.*, 2010).

According to Makkonen and Repka (2016), environmental regulations impose heavy costs and slows growth. This therefore hinders national and organisational competitiveness. Environmental taxes, technological standards and tradable emissions permits are examples of regulations that would force firms into allocating certain inputs, such as labour and capital investment, in order to reduce pollution. However, some companies may lack the resources that are required to invest on innovation (EC, 2013b). This is one of the problems faced by small and medium-sized enterprises that restrict their innovation activities, which usually revolves around difficulties with obtaining financing (EC, 2012a). From companies' business viewpoint, allocating the various inputs to reduce pollution were deemed to be unproductive as it diverts capital away from productive investments.

One generic example is in the case of installing new scrubbers in a power plant. The installation would result in an increase in the power plant's capital stock, but it would not increase the plant's productive capacity (Ambec and Barla, 2006). In other words, environmental regulation reduces firm's productivity and thereby increasing costs and lowering profits. There were other reasons that justified a negative relationship between environmental regulations and productivity in the power plant which includes:

- Emission control technology may reduce the production process efficiency;
- Environmental regulations may reduce investments if they increase energy prices, an input that is complementary to capital;
- Investments in abatement capital may crowd out productive investments;
- Stricter environmental regulations for new plants may delay introduction of new and more productive capital.

This traditional viewpoint that views environmental regulation as being costly and restricts growth for firms, was challenged notably by Porter (1991). Porter (1991) suggest that *"pollution is often a waste of resources and that a reduction in pollution may lead to an improvement in the productivity with which resources are used"* (as cited in Ambec *et al.*, 2011, p.2). Having stricter but properly designed environmental regulations can *"trigger innovation [broadly defined] that may partially or more than fully offset the costs of complying with them"* in some instances (Porter and van der Linde, 1995, p.98). **Figure 4-1** shows this relationship described by Porter (1991) which summarises the main casual links involved in the Porter hypothesis.

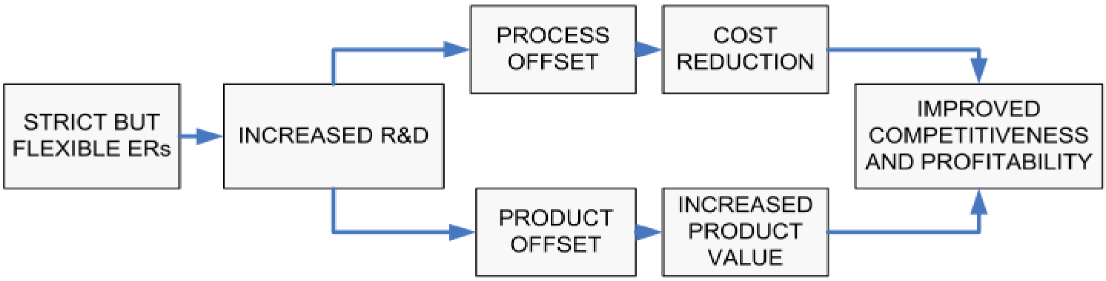


Figure 4-1 Schematic representation of the Porter hypothesis

Source: Ambec and Barla 2006 p.3

Porter and van der Linde (1995) also listed down at least five other reasons that can trigger innovation from properly designed regulations:

1. Regulation highlight to companies of possible resource inefficiencies and potential technological improvements.
2. Regulation that focuses on information gathering can achieve major benefits by raising corporate awareness.
3. Regulation reduces the uncertainty that investments to address the environment will be valuable.
4. Regulation creates pressure that motivates innovation and progress.
5. Regulation levels the transitional playing field.

In other words, well-designed environmental regulations can possibly lead to a ‘win-win’ situation in some cases, by not only protecting the environment, but also on improving profits and competitiveness through improvements of products, or through enhancement of product quality (Kesidou and Demirel, 2012). It is also important to consider that Porter hypothesis does not indicate all regulation leads to innovation. Only those regulations that are well-designed do. Furthermore, Porter hypothesis does not state that innovation necessarily offset the cost of regulation. It does however, make the claim that in most cases, these innovations will more than offset the cost of regulation (Ambec *et al.*, 2010).

More than often, companies must consider environmental regulations currently in existence or those that are enforceable in the future. This is due to their corporate environmental (and social) responsibility that exists in most companies; promoting the discussion on how the company provide their products in an ethically and environmentally sound performance (Yliskyla-Peuralahti and Gritsenko, 2014). These regulations are expected to lead to health and environmental benefits and more importantly, in encouraging companies find new ways of doing things (Makkonen and Repka, 2016). As such, there is the possibility that environmental regulation increases the need for higher research and development allocation for new environmentally friendly product innovations.

However, some companies may be unwilling to accept stricter environmental regulations. This is due to the fact that in most situations, the costs and benefits are levied on different industries and on different geographical areas, where some face the costs while others enjoy the benefits (Makkonen and Repka, 2016). Companies may even have decided to ‘go green’ even without environmental regulations, but the strict timeline imposed or the method of implementation may have caused them to show resistance (Lambertini and Tampieri, 2012).

A number of studies have been carried out throughout the years to empirically test the statements made by Porter (1991) (Jaffe *et al.*, 1995; Popp, 2006; Horbach, 2008; Doran and Ryan, 2012). It was found that there is relatively little evidence to support the hypothesis. Research on validating Porter hypothesis has not produced a consensus (Ambec *et al.*, 2010): some studies are in favour of and some against, whereas others remain inconclusive. This research is not focused on testing Porter hypothesis but is focused on investigating the variables that encourage or restrict product innovation in the marine equipment sector; with environmental regulation being one of the variables that encourage innovation.

4.2.2 Innovation inducement impact of IMO regulations

Regulations imposed by the IMO is built on a scientific basis and continuously pushes for technology development and innovation within the industry. Some of IMO regulations trigger innovation while others adopt what has already been embraced as best practice in the industry (IMO, 2013a). As explained and covered in **Chapter 3.4**, stricter regulation has been implemented by the IMO with regards to the amount of sulphur content allowed in fuel. In effect, ships will be required to use alternative fuel (more expensive low sulphur fuel or liquefied natural gas) or to retrofit their ships with abatement technologies onboard to comply with the stricter regulation. The IMO has also included a NOx reduction scheme for new ships, where ship-owners can meet the standards by retrofitting their vessels with NOx Reducer (NOR) or switching to liquefied natural gas (Bunkerspot, 2014).

One measure that is already being used that may result in significant reduction in fuel consumption, and consequently reduce emission, is slow steaming (Kontovas and Psaraftis, 2011). Taking reference to the containership traffic, slow steaming in that category of ship-type has resulted in the reduction of emission level by approximately 11 percent (Cariou, 2011). Energy-saving engines and more efficient propulsion systems are other examples of innovations induced by environmental regulations. However, these are considered as incremental innovations.

A concrete example of new product innovation includes scrubber systems and *Flettner rotors* that can be used to comply with stricter regulation by the IMO. Although scrubber systems has had a long history in the shipping industry, it was hardly used in the past as the system still required extensive technological research and development and technical adjustments to finding solutions in fitting the systems onboard ships (Henriksson, 2007). The same is said for Flettner rotors. Due to the lack of literatures available, this research attempts to investigate the drivers for such product innovation in the marine equipment sector and to establish whether IMO regulations induce innovations.

4.3 Alternative fuels

One of the ways the shipping industry can meet the 2020 global sulphur regulation is by using alternative fuel. Instead of using HFO which is high in sulphur content, ship-owners can switch to using other types of fuel that have a lower sulphur content that meets the standards of the regulation.

4.3.1 Low-sulphur fuel

Low-sulphur fuel (LSF) is one of the alternative fuels the shipping industry can use to comply with the stricter regulation. The switch to LSF has been opted as one of the best solutions for emission reduction (Tay, 2011).

As there is no universally accepted refining method to produce 0.5 percent sulphur fuel, the market for these fuels may be fragmented, with several different specifications on offer (Jordan and Hickin, 2017). This is based on the experience of the northwest of Europe when implementing its 0.1 percent sulphur emission control area at the beginning of 2015. As such, ship-owners that are considering switching to LSF will need to consider the variety of terminology being used in the market to define LSF. Some of these terminologies are misleading; making it crucial for ship-owners not be confused, and to be fully aware of the fuel classification for LSF (Einemo, 2017). The International Bunker Industry Association (IBIA) has come up with a solution to assist ship-owners in understanding the different terminology.

One of the solutions highlighted by IBIA is to understand the key operational differentiator for the fuel: whether the fuel requires to be kept heated to remain in liquid form when stored in ship's fuel tanks and during transfer onboard (Einemo, 2017). Should the fuel require heating, it is classified as a residual marine (RM) fuel. If heating is not required, the fuel is classified as a distillate marine (DM) fuel oil.

The terminology is also distinct when it comes to differentiating between fuels meeting a 0.1 percent sulphur limit and a 0.5 percent sulphur limit. Ultra-low sulphur (ULS) are given to fuels with up to 0.1 percent sulphur content. Fuels that are above 0.1 percent, but meeting a 0.5 percent sulphur limit, are called very-low sulphur (VLS). Lastly, all the products can be called fuel oil (FO), which is in line with the terminology used in MARPOL Annex VI, which calls all fuels for marine consumption as 'fuel oils'. From this, the following terminology was derived:

- RM: residual marine (fuel that requires heating)
- DM: distillate marine (fuel that does not require heating)
- FO: fuel oil
- ULSFO RM: maximum 0.1 percent sulphur RM product
- ULSFO DM: maximum 0.1 percent sulphur DM product
- VLSFO RM: RM products that are above 0.1 percent but meeting a 0.5 percent sulphur limit
- VLSFO DM: DM products that are above 0.1 percent but meeting a 0.5 percent sulphur limit

It is predicted that the switch to 0.5 percent sulphur fuel will cause more changes to global marine industry in terms of fuel demand, as compared to the 0.1 percent sulphur fuel switch in ECAs (Shell, 2017). It was estimated that this switch represents about 75 percent of global marine fuel demand when compared to the demand of ECA. Approximately 3 million barrels per day (mbd) of high sulphur fuel oil bunkers will need to switch to 0.5 percent sulphur fuel (through blending with other types of fuel) to meet this demand.

Ship-owners intending to switch to burning LSF needs to consider the challenges it comes with, such as the possibility of damages to the main engine caused by the high presence of catalytic fines and abrasives found in the fuel (Tay, 2011). Another issue is to do with its lubricity, which is crucial for reducing friction between solid surfaces in relative motion (Infineum, 2016).

Compared to conventional fuels, LSF have low natural lubricity which can increase fuel pump and injector wear. However, this can be overcome by using special lubricants that are specifically designed to protect main engines burning LSF from wear and deposits (Shell, 2017). Additives may also be added in order to maintain lubricity performance (Infineum, 2016). It is crucial for ship-owners to ensure their ship's engines, pumps, boilers and boiler burners are correctly adjusted for the burning and maintenance of LSF (PRS, 2009).

The cost of switching to burning LSF is another factor that needs to be considered. Fuel cost accounts for the largest share of total ship's operating costs, as seen in **Figure 4-2**. As such, any changes to the price of fuel will ultimately affect the relative cost structure of the day-to-day running of the ship. In the scenario where fuel price increases, its relative share of the day-to-day cost will also increase; resulting in the overall operating cost of the ship to rise. This is the reason ship-owners are interested in knowing the price they would have to pay for 0.5 percent sulphur content fuel.

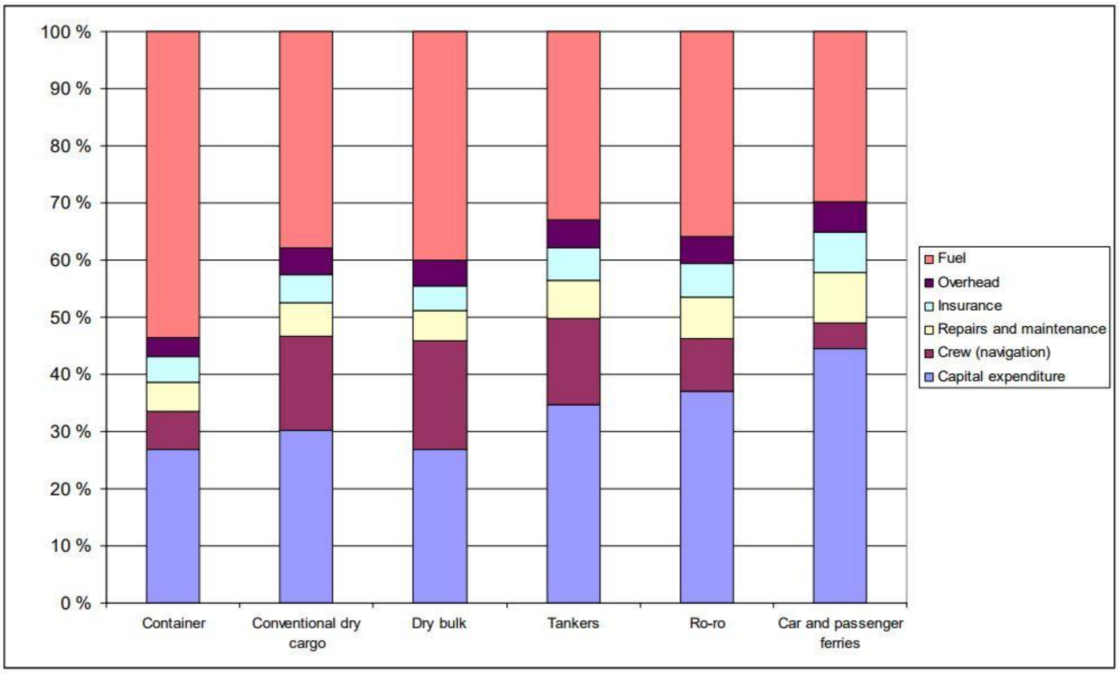


Figure 4-2 Distribution of ship's cost

Source: Kalli *et al.* 2009 p.8

As the process involved in the production of LSF, which is equivalent to distillates, is more complicated than the production of HFO, the cost of LSF is high (Kalli *et al.*, 2009). The use of gas oil to product the 0.5 percent sulphur blend also drives up its cost. Furthermore, the price of LSF is set to increase even more as the 2020 global low sulphur regulation comes into force. This is due to further increase in demand for LSF to meet global regulation, in addition to demand to meet ECA and EU regulation; resulting in the potential decline of HFO (Infineum, 2016; Shell, 2017). Currently, there is no consensus over what price premium should be expected for LSF over the current global standard of 3.5 percent sulphur content bunker fuel (Molloy, 2016). However, it is expected that LSF being supplied at a premium rate will diminish once the initial phase of complying with the 2020 regulation has passed (ABS, 2013).

Although the actual price impact will not be known until 2020, *"the forward curves are already pricing in the likelihood of a dramatically different fuel oil market"*

(Molloy, 2016, p.6). According to the Intercontinental Exchange, a financial market company, *“the calendar-year 2019 fuel oil crack … has fallen to minus USD14.78* [per barrel], *its lowest-ever level”* recorded on October 27, 2016; the day the IMO decided to go ahead with the 2020 implementation date (as cited in Molloy, 2016, p.6). The decline in price is an indication that the market anticipates demand for high sulphur fuel oil to drop in the run-up to the 2020 implementation date.

Aside from the high cost of LSF, ship-owners also have to consider the deliverable quantity of the fuel from suppliers, as some may have a minimum quantity requirement before supplying to the ship (ABS, 2013). This means that the minimum requirement amount may be more than what the ship requires or is able to accommodate. As such, ship-owners need to consider the different requirements and practices established by each port for LSF bunkering.

Ship-owners whose ships are trading within ECAs will also need to consider the type of low sulphur fuels used, to comply with not only the 0.5 percent sulphur limits but also the 0.1 percent sulphur limits in those areas. This is in addition to ships at berth or anchorage in EU ports which are also subjected to those limits. Therefore, it is crucial for these ship-owners to consider purchasing a fuel that complies with all regulations or having two different fuel types. This is dependent on how often their ships trade within 0.1 percent sulphur limit areas, including potential future ECAs.

It will also be dependent on the price difference between 0.1 and 0.5 percent sulphur content in fuel. It is predicted that under current circumstances, a 0.5 percent sulphur bunker fuel could be expected to trade at a discount to 0.1 percent sulphur MGO (Jordan and Hickin, 2017). If the price differential between the two types of fuel are significant, ship-owners may consider the ‘changeover method’, which involves using segregated tank design where the ship switches between the two different fuel types (Yang *et al.*, 2012).

4.3.2 Liquefied natural gas

The use of liquefied natural gas (LNG) as marine fuel has been around for many years, but primarily used on LNG carriers as ‘the boil off’ gas (Herdzik, 2011). Otherwise, it was found to be used only on a relatively small number of niche or specialised ships (Royal Institute of Navel Architects [RINA], 2017). However, the rise in stricter environmental regulations within the last decade has led to an increase in LNG-fuelled ships (Herdzik, 2011).

A type of natural gas, LNG is converted to liquid state through a process of ‘liquefaction’ (Foss, 2007). This involves decreasing the temperature of the gas that reduces its physical volume by approximately six hundred times; making storage and transportation of LNG more operationally manageable and economically feasible (Aymelek *et al.*, 2014). LNG is a proven and available commercial solution that presents ship-owners with significant advantages for using it as a fuel for their ships (Det Norske Veritas-Germanischer Lloyd [DNV-GL], 2015).

One of the most beneficial advantages for ship-owners using LNG as fuel is it reduces harmful emissions from ships. LNG is virtually sulphur free that compared to conventional heavy- and low-sulphur fuel oil, LNG-fuelled ships emit hardly any PM, about 90 percent less SOx and up to 90 percent less NOx (DNV-GL, 2015; MSLGROUP and PwC, 2015). The environmental benefits in terms of emission savings makes LNG an attractive fuel for shipping industry to meet the 2020 global low sulphur regulation. It comes without surprise that LNG is the most heavily promoted alternative fuel source, instead of LSF, in meeting the regulation (RINA, 2017).

Another advantage to using LNG is its cost. Currently, the price of LNG for existing contracts are predominantly index-linked to the price of HFO or marine fuel oil (MSLGROUP and PwC, 2015). Although pricing scheme for LNG fuel has yet to be fully developed, it is often cheaper compared to HFO (Herdzik, 2011). This makes LNG fuel commercially attractive for ship-owners to consider switching to, for complying with the 2020 low sulphur regulation (MSLGROUP and PwC, 2015).

As of 2015, 63 LNG-fuelled ships were already in operation worldwide; with a further 76 new-buildings confirmed for the ship-type in the same year (DNV-GL, 2015). Although LNG-fuelled ships were initially slow to materialised, the shipping industry has seen a steady expansion for the ship-type in recent years, as seen in **Figure 4-3**.

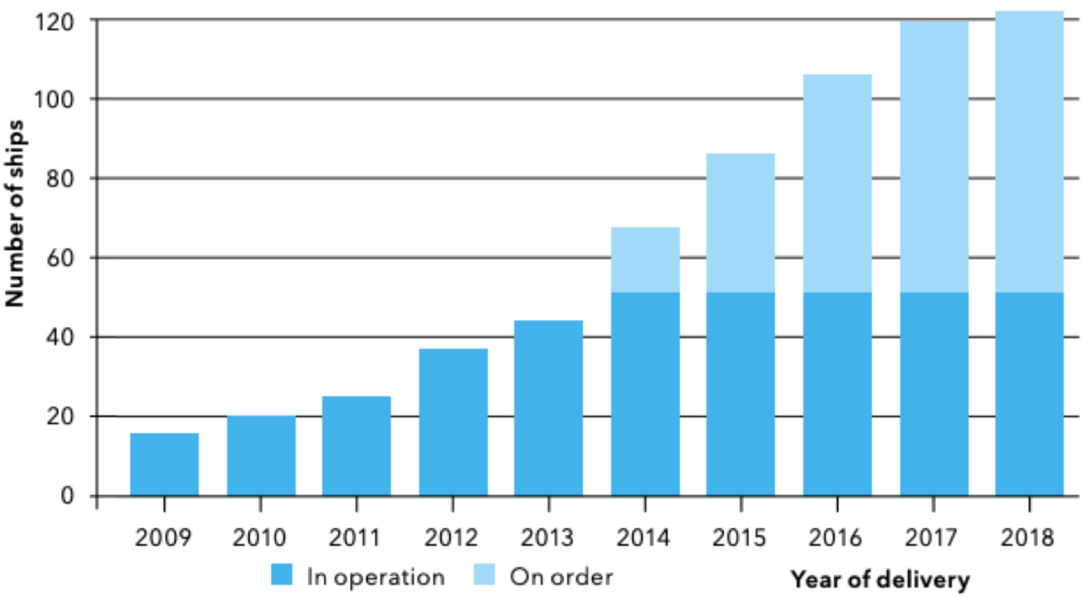


Figure 4-3 Development of LNG-fuelled ships

Source: DNV-GL 2014 p.49

However, there are challenges involved with using LNG as fuel for ships which ship-owners need to consider. This may include having to factor in the size of LNG storage tanks onboard ships, which are approximately two and a half times larger compared to conventional fuel/gas oil tanks (Herdzik, 2011). This is due to the properties of LNG having smaller density as compared to that of conventional fuel such as marine gas oil, and the need for thermal shield. Ship-owners therefore must take this into consideration as the size of LNG tanks represents a significant loss of cargo space for most ship-types.

According to MSLGROUP and PwC (2015), other disadvantages also include:

- *Incompatibility with existing engine types*. Traditional ship engines and fuel systems need to be modified to be able to use LNG as fuel onboard. This is due to natural gas not being compatible with existing liquid fuel engines.
- *High costs of investment*. Ship-owners are required to invest more in expensive ship technology such as gas engine, gas fuel system and LNG storage tanks (including insulated piping). These added investments will cost ship-owners between 10 to 30 percent higher as compared to investments for conventional ship technology.
- *Increased safety requirements*. Due to the properties of LNG, additional safety requirements are needed over traditional fuel. Setting these requirements in place results in additional costs for ship-owners and operational limitations.
- *Lack of infrastructure.* The lack of LNG bunker facilities makes it difficult for ships to rely on LNG as fuel; especially if the ship is unable to depend on regular seagoing routes. There are a few LNG bunker facility sites which has been established, but most of these are in ECAs.

Although the infrastructure for LNG is costly, Sahu (2017) predicts the uptake of LNG as bunker fuel is expected to rise. This is mainly due to the push for LNG as bunker fuel is not coming just from the suppliers, but also from governments and ports. As ports such as Singapore, Japan and South Korea are geared up for LNG bunkering, the availability of LNG is on the rise; making LNG more available and easily accessible in the future.

4.3.3 Methanol

Methanol as bunker fuel is another alternative ship-owner can consider switching to, in order to comply with the 2020 low sulphur regulation. Methanol is a clear, colourless liquid that dissolves quickly in water and biodegrades rapidly. As such, in instances of a large methanol spillage, its effects on the environment will be much lower as compared to those from an equivalent oil spillage (Sahu, 2017).

Methanol is mainly produced from natural gas, but the fuel can also be produced through renewable sources such as biomass, recycled carbon dioxide or agricultural and timber waste (Adams, 2016). Methanol can also be produced by using a gas mixture consisting of hydrogen and carbon monoxide, which are known as synthesis gas (Aasberg-Petersen *et al.*, 2008). Through several processes, the synthesis gas is converted to liquid hydrocarbons (methanol).

The advantages of using methanol as fuel is that it reduces the emissions of SOx, NOx and PM significantly (Sahu, 2017). However, the use of methanol in the maritime industry is currently limited (IMO, 2016b). The use of methanol as bunker fuel was only recently considered in the last few years; partly due to the surge in production capacity (Sahu, 2017).

In March of 2015, *Stena Line* launched the world's first methanol powered ferry (RINA, 2017). During the pilot project, the company found that the benefits of running on methanol include ease of transportation and storage of the fuel. This is due to the properties of methanol being similar to bunker fuel, in which both are liquid; making it a better alternative than using LNG which requires its own infrastructure (Lewenhaupt, 2017; Sahu, 2017).

Then in 2016, the first of seven ocean-going ships fitted with dual fuel engine came into service (Adams, 2016). When running on methanol, these ships can reduce SOx and NOx emissions by approximately 95 percent and 30 percent respectively, as compared to conventional marine diesel oil. These ships are also able to run on fuel oil, marine diesel oil or gas oil.

Methanol can therefore be an attractive alternative marine fuel for ship-owners in the future due to its lower fuel costs and easier handling of the fuel with existing storage and bunkering infrastructure. Furthermore, the costs associated with building or retrofitting ships to run on methanol is also considerably lower when compared to other alternative fuel conversions (Adams, 2016). Ship-owners can also be certain that the supply of methanol is constant, due to the fuel being one of the top five chemical commodities that are shipped around the world each year. As such, methanol is available around the world through existing global terminal infrastructure for ship-owners to receive their supply (Adams, 2016).

4.3.4 Biofuels

Biofuel is a type of fuel that is biodegradable, non-toxic and are practically free of sulphur and aromatics. The most common types of biofuels are ethanol and biodiesel.

Ethanol is essentially pure alcohol which is made from various sources such as corn and sugarcane. One of the benefits of burning ethanol is that the fuel burns cleaner than gasoline; releasing roughly 15 percent less harmful emissions (Writer, 2011). There are however, downsides to burning ethanol as a fuel source. One of the disadvantages is to do with its sustainability, where the production of ethanol is not sustainable. This is due to the production of ethanol, which derives from crops such as corn, beets and sugarcane, is competing directly with the food supply. In addition, the use of toxic industrial agrochemicals that are used to farm ethanol crops, can contaminate water supplies (Writer, 2011). Furthermore, the cost of ethanol production can also be costly; resulting in the end user paying a premium price for the fuel.

Biodiesel on the other hand, is a type of biofuel derived from vegetable or animal oils. The burning of biodiesel as a fuel has several advantages compared to burning regular petroleum diesel. One of the advantages of biodiesel is that it burns cleaner than conventional diesel. This is due to the fuel producing significantly lesser harmful emissions compared to regular petroleum diesel. According to Zuleta *et al.* (2012), this will eventually reduce global dependency on petroleum as biodiesel is not a petroleum-based fuel. Its benefits also include not competing directly for agricultural land for its production; making it more sustainable compared to ethanol.

Although the production of biodiesel can also derive from used cooking vegetable oils or from wastes and algae, which makes it production sustainable, it is an expensive process (Prati *et al.*, 2015). The use of biodiesel as fuel also has some performance disadvantages. As biodiesel is susceptible to cold weather, its use may cause issues related to fuel injection. This occurs as the fuel converts into gel state when the temperature drops (Writer, 2011; Zuleta *et al.*, 2012). Furthermore, wax crystals can also form at low temperatures which can clog up fuel lines and filters in the fuel system.

According to RINA (2017), there are currently a small number of ships that uses sustainable or renewable biofuels. Using biofuel as an alternative to conventional fuel is currently uncommon among ship-owners in the industry due to several reasons, including high cost and availability. More importantly are the issues associated with storage of the fuel due to the oxidative stability of biofuel that can affect the quality and the materials it comes in contact with. As such, it is crucial that external factors such as the presence of oxygen, light and the exposure to contaminated substances (metals and free radicals) are controlled in order to avoid oxidation (Zuleta *et al.*, 2012). In some cases, long term storage of the fuel can result in the quality of the fuel to be unstable and also led to micro-biological growth (RINA, 2017). For these reasons, using biofuels to meet the 2020 global sulphur regulation seems unlikely for the time being.

4.4 Technological products

This section looks at technological solutions available for ship-owners to meet the 2020 low sulphur regulation. Some of these products are in the development stage and others are already available in the market, ready for ship-owners to adopt and implement on their ships.

4.4.1 Wind technology

Other than the 2020 global low sulphur regulation, fluctuating oil prices and commercial pressures has led to the shipping industry to turn to developing new technologies to keep up with changing times. Taking a modern take on one of the earliest forms of ship's propulsion, marine equipment manufacturers are looking back into harnessing power from the wind. Argyros (2015), defines wind-assisted propulsion as *"the use of a device, such as a wingsail, soft sail, kite or Flettner rotor to capture the energy of the wind and generate forward thrust"* (p.4).

Although a few wind propulsion systems have been under development for a few years, the technology has only recently gain commercial recognition and are in demand from the shipping industry (Grey, 2016). This is due to the industry having realised that wind propulsion is a good source of renewable energy. In addition, wind propulsion ships are becoming a more viable solution for commercial shipping market in the near future; resulting from the rise in award-winning propulsion systems by equipment manufacturers.

There are currently five different types of wind propulsion technology. Each of these technologies are at different phases of development and implementation, and each with their own set of advantages for end users. The first type is (1) wind turbines, which currently does not have successful prototypes to date. The sail-based systems featuring (2) soft, (3) fixed and (4) kite sails on the other hand, are already being retrofitted and used onboard ships. Finally, is the (5) Flettner rotor, which is close to commercialisation and is currently the world's top-performing wind propulsion system (Grey, 2016).

The amount of fuel savings associated with using the different types of wind propulsion technology highlighted above, varies widely from five percent to as much as 80 percent; depending on the technology and type of vessel used (Grey, 2016). Despite the stark difference in savings, wind-assisted propulsion is one of the few technologies available in the market that is able to offer ship-owners with significant fuel savings (Argyros, 2015).

Furthermore, the factor that makes wind propulsion technology attractive is the stability it creates in the current unstable transitional period in fuels and propulsion options, with regards to the 2020 low sulphur regulation. Having this stability and certainty will significantly benefit ship-owners in the highly uncertain marketplace; where the future of where the industry is heading remains unknown (Grey, 2016).

There are currently three different types of wind propulsion systems available in the market for ship-owners to adopt and implement on their ships: *Norsepower* rotor sail solution, the *Aquarius* project, and *SkySails* propulsion method.

4.4.1.1 Norsepower rotor sail solution

The rotor sail solution, an upgraded version of the Flettner rotor, is currently the market leader amongst wind propulsion systems. The technology consists of a spinning cylinder that uses the Magnus effect to harness wind power, in order to propel a ship. This works by having wind passing through the spinning rotor sail; resulting in air flow accelerating on one side and decelerating on the opposite side. This then creates a thrust force that is perpendicular to the wind flow direction (Aggidis, 2017). The thrust produced by the rotor sail meant that the main engine of the ship can be significantly throttled back; resulting in a reduction in the overall fuel consumption and emission rates.

The rotor sail consists of lightweight composite materials that allows for a simple, yet structurally sound and high technology solution (Hellenic Shipping News, 2016). The sail reduces crew time and resources as it is fully automated, where the rotors will start automatically once it senses surrounding winds that are strong enough to deliver fuel savings for the ship (Hellenic Shipping News, 2016). When the system is active, the ship's main engine will throttle back to allow fuel saving and reduced emissions, whilst providing the power needed to maintain the ship's speed and voyage time.

The technology was tested out on two sea trials onboard merchant ship *Estraden*, a 9,700-deadweight tonnage roll-on/roll-off carrier. The sea trials proved successful with verified data showing that a single small rotor sail on the ship's route in the North Sea, had resulted in a fuel saving of approximately three percent (Bore, 2017). The result confirmed Norsepower's rotor sail of being able to produce substantial amounts of thrust force to allow for considerable fuel savings. Based on the initial result, Norsepower is confident that *Estraden* is able to potentially deliver five percent efficiency savings on an ongoing basis, when the ship is fitted with a full system of two rotors onboard (Frith, 2015).

Independent data analysis also shows that fuel savings of up to 20 percent per year can be achieved if the ship is fitted with multiple large rotors and travelling on favourable wind routes at an appropriate service speed (Norsepower, 2017). Each rotor sail will set ship-owners back by approximately more than 1.5 million British pounds to install (Aggidis, 2017). However, taking into consideration the amount of savings in fuel costs, it has been estimated that the payback period for the system will be less than four years (Bore, 2017).

Norsepower rotor sail solution is the first data-verified and commercially viable auxiliary wind propulsion system that reduces fuel and carbon emissions, that is available on the market. The technology can be installed on new-build ferries, roll-on/roll-off vessels, tankers and bulk carriers. There is also the possibility of retrofitting the system onboard ships. This only requires a quick harbour-based installation of seven hours; thereby eliminating off-hire costs. The company hopes that their sails are able to reduce average fuel consumption on typical global shipping routes by seven to 10 percent, which is the equivalent of about 1,000 tonnes of fuel a year (Aggidis, 2017).

The concept of Flettner rotor has always been to create additional propulsion for ships from the wind; thereby reducing fuel consumption. However, German researchers are currently further developing the concept by having the rotors create synthetic gas (power to gas or P2G) (Rutkowski, 2016). This is where the rotating turbine, which kept in motion by the ship's kinetic energy, is used to generate electricity. Synthetic gas is then created by means of electrolysis. From this process, the gas generated can then be used as a fuel or to generate electricity for the ship (Rutkowski, 2016).

Another organisation also actively making improvements to the Flettner rotor concept is by Switzerland-based *THiiiNK Holding*. The organisation has developed and patented new technologies to optimise the performance and adoption of Flettner Rotors. Named the *THiiiNKSail*, the system uses large scale rotor fitted with a sail flap, which gives superior performance particularly for narrower 'upwind tacks' (Thiiink Holding, 2017). The system is also retractable to allow for easier access to ports, ability to navigate bridges and the ability to stow the rotors in adverse weather conditions whilst at sea. According to the organisation, their improved Flettner rotor designs has resulted in an improved rotor performance by 50 percent or more. Furthermore, their system has an improved internal rate of return of up to 55 percent as compared to a standard rotor (Thiiink Holding, 2017).

4.4.1.2 The Aquarius project

In mid-2010, a project called the *Aquarius MRE* (Aquarius Marine Renewable Energy) was started in Japan by Eco Marine Power (EMP). The company was developing a commercial system that utilises both wind power and solar energy onboard ocean going ships, to significantly reduce ships fuel consumption and to lower noxious gas emissions (Eco Marine Power [EMP], 2017).

The system consists of advanced integrated system of rigid sails that were installed with marine-grade solar panels, energy storage modules and marine computers. The array of rigid sails, or EMP's Energy Sail technology, were positioned automatically by a computer system that detects the best position based on prevailing weather conditions (Rutkowski, 2016; EMP, 2017). This system enables the ship to tap into renewable energy by harnessing the power provided by the wind and sun. These sails can also be lowered and stored when not in use or when the vessel is in bad weather conditions (Rutkowski, 2016). Typically, EMP's Energy Sail array is incorporated into an Aquarius MRE system as a one-stop solution, but the installation of an Energy Sail as a standalone device is also possible. The system is suitable for ocean-going ships including roll-on/roll-off ships, cruise ships and large passenger ferries.

Due to the flexible nature of the Energy Sail design, the sails can be upgraded throughout the life-cycle of the ship that it is fitted on. This will allow newer technologies to be incorporated on the sails as they become available such as more efficient solar modules or panels, or other technologies including wind power generating devices (Rutkowski, 2016).

The key features of the Aquarius MRE system includes patented technology, ease of use, robust design, fully automated control system, attractive return on investment and reliable operation (EMP, 2017). Aquarius MRE can easily be incorporated into existing ships designs or be integrated into future designs for ship-owners and operators to reduce the emission rate of their fleet.

4.4.1.3 SkySails propulsion method

SkySails, a Hamburg-based company, were looking at re-harnessing the wind for ship propulsion with its SkySails propulsion method. The system was designed as an auxiliary propulsion system to help ship-owners and operators offset the environmental and financial costs associated with running their ships on diesel engines. When active, the kite-system moves the ship forward; consequently, reducing the load on the engine. As a result, the ship's fuel consumption decreases simultaneously.

The system consists of a towing kite that is capable of flying in strong winds 100 metres to 300 metres above the ship, a launch and recovery system and a control system for automated operation (Lo, 2013). In favourable wind conditions, the system is able to generate up to 2,000 kilowatt of propulsion power, which is approximately up to 25 times more energy per square metre as compared to conventional sails (Lo, 2013). According to the technology's founder and Chief Executive Officer (CEO), Stephan Wrage, this equates to significant cost and emissions savings even in variable conditions (Lo, 2013).

It was estimated that the company's newest SkySails system, the *SKS C 320*, can save ship-owners and operators up to 10 tonnes of oil per day in good wind conditions. This equates to approximately USD 5,000 in fuel cost savings and more than 30 tonnes of emission savings per day (Lo, 2013). However, since wind conditions are unpredictable, and it varies, the system on average can realistically save ship-owners and operators two to three tonnes of oil per day.

One of the additional advantages of the system is the ease of installation. The SkySails system can easily be installed on new-builds or retrofitted onboard existing ships without the need for any significant modifications. When in use, the system does not compromise normal operations of the ship, including loading or unloading operations, and the vessel will remain fully manoeuvrable (Lo, 2013; Rutkowski, 2016).

The system's innovative use of wind energy has been implemented onto several types of cargo ships with favourable results. It has been proven that the technology was able to reduce fuel consumption on ships when the kite was being used in strong winds. This was evident in the case of *Aghia Marina*, a 170-metre-long dry bulk ship transporting agricultural and industrial raw materials and commodities. The ship was equipped with the world's largest kite power technology back in 2012, as an auxiliary wind propulsion system produced by SkySails (Dasgupta, 2016). The 320-square metre kite was connected to the ship by a rope and flew in a figure-of-eight formation at a height of between 100 metres to 420 metres. The system enabled the ship to cut down on its SOx and NOx gas emissions by up to 35 percent in favourable wind conditions, in addition to reducing the ship's fuel consumption.

4.4.1.4 Obstacles to wind propulsion

In recent years, there have been an increase in the number of ships that are equipped with wind propulsion technology, brought about by the rise in the number of projects that were in the pipeline (Grey, 2016). This include the Eco Flettner that was fitted onboard *Fehn Pollux,* a ship from Germany-based Fehn Ship Management, in 2016 (International Transport Journal [ITJ], 2015).

Four of the Flettner rotor was also fitted onboard the 13,000-deadweight tonnage roll-on/roll-off cargo ship named *E-ship1*; one of the largest ships to use the system. The four-large rotor-sails rotates at variable speed to create lift on the cylindrical body by means of the Magnus effect (the perpendicular force that is exerted on a spinning body moving through a fluid stream). *Enercon*, the operating company, claims that the vessel has achieved a fuel savings of 25 percent after sailing a total of 170,000 miles (Grey, 2016; Rutkowski, 2016).

Most of the wind propulsion systems have been tested and are proven to be reliable as a method of improving energy efficiency and reducing fuel consumption. However, looking back at the different types of wind propulsion technology available in the market for ship-owners to adopt, the concept of harvesting wind technology still has a few practical and ideological obstacles to overcome. This is despite the technology having already established a presence in the shipping industry.

Some of these obstacles relate to the general lack of research and development carried out by ship-owners in implementing the technology onboard and difficulties in getting finances for the system due to limited capital ship-owners have access to (Grey, 2016). Furthermore, there may also be issues with regards to the wind power reliability and predictability on some of the more arduous trade routes that result in ship-owners unwilling to adopt the technology (RINA, 2017). These are the factors that may contribute to a slow adoption rate of the technology within the shipping industry.

However, the biggest challenges identified by Grey (2016) is 'internal perception'. According to Grey (2016), the shipping industry has always been quite conservative when it comes to adopting new technologies, and companies do not necessarily want to be seen as a first mover on a particular product. As such, wind propulsion providers need to change the industry's perspective on the technology to encourage more uptake of the system. The International Windship Association (IWSA), a collaborative organisation established to facilitate and promote wind propulsion for global commercial shipping, is also working with naval architects, engineers, classification societies and regulators to smooth out some of the issues and barriers related to the uptake of the technology among ship-owners.

The IWSA is also providing assistance to its members (wind technology manufacturers) to reduce the risks associated with investing in wind propulsion technology, by providing them with finance packages and in helping them to deal with banks and ship-owners (Grey, 2016). As it is crucial to engage with ship-owners at a time when they start to realise wind propulsion technology is credible and viable, the IWSA also aims to provide ship-owners with necessary information regarding the system, and to provide them with a comparison of the different type of technologies available.

Having more demonstration or trial ships in the water to generate more statistical data for ship-owners to gain more information regarding the system, can also eventually convince them to adopt the technology (Aggidis, 2017). The increase in presence of such ships in the waters will hopefully convince ship-owners that wind propulsion system is the way forward in the challenging future with regards to more stringent environmental regulations. This will potentially make investment in rotor sails much more worthwhile.

4.4.2 Exhaust gas scrubbers

Abatement technology such as scrubbers is another alternative solution available for ship-owners to consider in meeting the global low sulphur regulation of 2020. Typically, reducing SOx emissions is regulated by mandating reductions on the sulphur content of the fuel, but there are still issues with regards to the availability and price of these compliant fuels.

Beyond upgrading refineries to produce more distillates for ship-owners, the other principal means of reducing marine sulphur emissions is by cleaning the emissions onboard ships. There is growing interest and application for exhaust gas cleaning systems that can provide ship-owners with an alternative means of complying with the 2020 low sulphur regulation (ABS, 2013). According to Molloy (2016), having more scrubbers installed on ships will result to lower number of ship-owners switching from heavy sulphur fuel oil to 0.5 percent blend. As such, this will place lesser strain on the global refining system.

Exhaust gas scrubber systems that are commonly proposed to be used for shipboard application consists of two basic concepts: the dry scrubber-type and the wet scrubber-type. There is also the membrane type scrubber that ship-owners can install onboard ships. Currently, there are several companies that offer ship-owners with wet scrubber systems: Alfa Laval, Clean Marine, Wärtsilä and Clean Air Technologies. These are some of the companies that had a competitive advantage over other companies for taking the early initiative in developing and producing the systems (Kalli *et al.*, 2009). Dry scrubber systems on the other hand, only entered the market in recent years (Lappi *et al.*, 2012), and membrane type scrubber is the most recent type to enter the market.

In general, a scrubber is a device that is *"installed in the exhaust system after the engine or boiler that treats the exhaust gas with a variety of substances including seawater, chemically treated fresh water or dry substances, so as to remove most of the SOx from the exhaust and reduce PM to some extent"* (ABS, 2013, p.15). After the scrubbing process is completed, the cleaned exhaust is emitted into the atmosphere. SOx and PM that is removed from the exhaust, along with substances that were used for the cleaning process, are channelled into a waste stream. The waste stream and generated sludge from the scrubber will have to be processed as per IMO guidelines before being discharged overboard, where allowed, or stored and discharged to shore as a waste substance.

4.4.2.1 Dry scrubbers

In a dry scrubber, no water or any liquids are used during the scrubbing process. However, substances, normally calcium hydroxide, are introduced into the exhaust gas to cause a chemical reaction that removes the SOx emission compounds (ABS, 2013). As the exhaust is not required to pass through water to be cooled for scrubbing process, dry scrubber units can be placed before an exhaust gas economiser. This will utilise the otherwise wasted heat from the exhaust gas of diesel engine, that can be used to produce energy or heating.

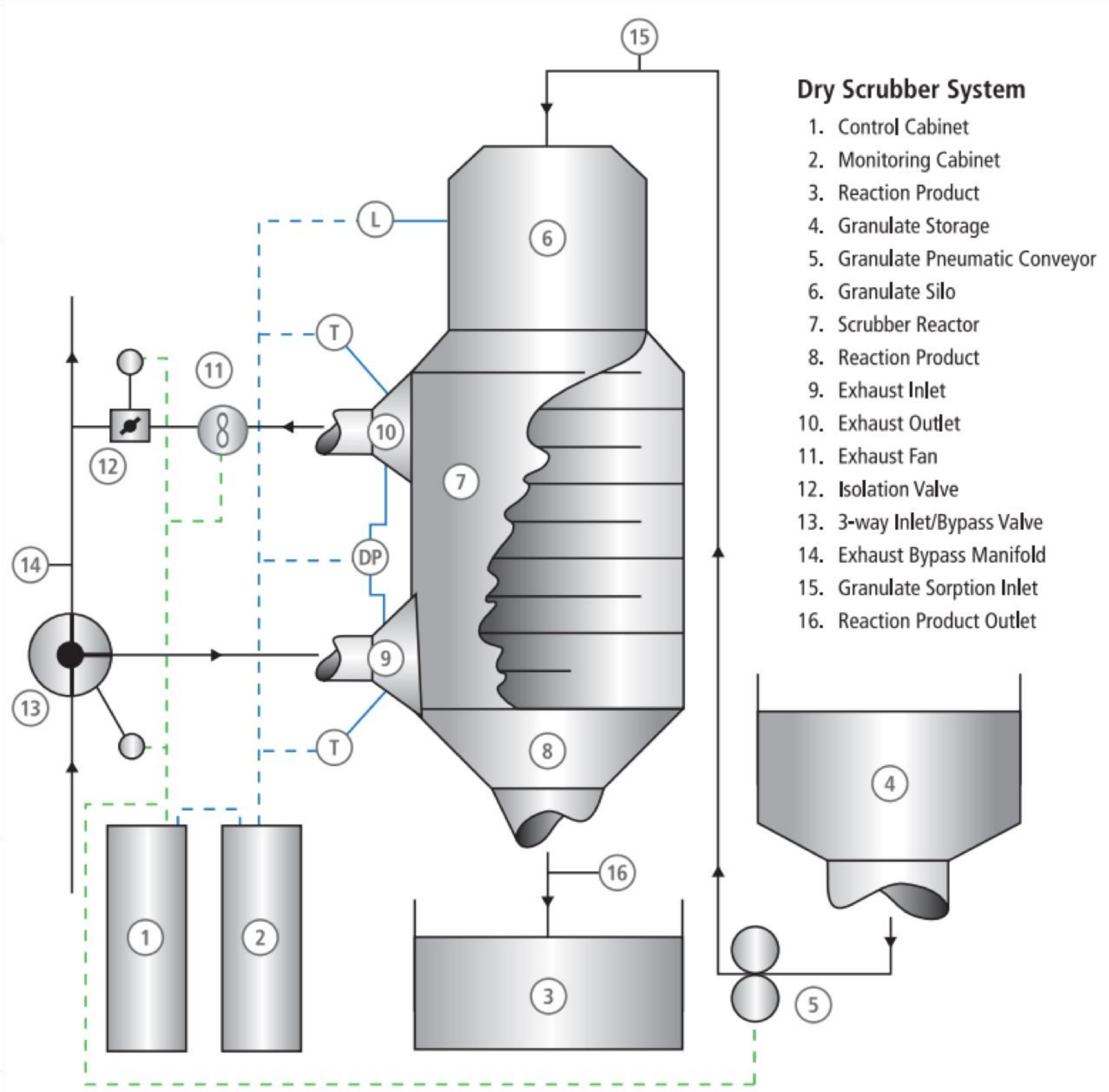


Figure 4-4 Schematic drawing of a dry scrubber unit

Source: Tran 2017 p.4

Dry scrubbers are more commonly found and used on land-based exhaust gas cleaning installations. For this reason, dry scrubbers are not readily available to ship-owners for use onboard ships. There are however, dry scrubber units that have been specially developed for marine use such as *DryEGCS*. The product, manufactured by Germany-based *Couple Systems,* operates by feeding dry pellets of granulated calcium hydroxide through a packed bed absorber. This will then react with the hot exhaust gas where SOx components are absorbed to form solid calcium sulphate, which is a non-toxic harmless substance (ABS, 2013). The calcium sulphate is then removed from the absorber and stored onboard to be disposed of when the ship is ashore. The transport of calcium sulphate to and from the absorber is achieved pneumatically. In situations when the dry scrubber is not in operation, or when its operation is not needed, an exhaust gas bypass is required.

4.4.2.2 Wet scrubbers

Wet scrubbers involve having the exhaust gas passing through a liquid media for the removal process of SOx compounds to take place. The exhaust gas will react chemically with parts of the wash liquid for SOx removal. The liquids used in wet scrubbers are commonly either untreated seawater or chemically treated fresh water.

The usage of seawater is normally used in an ‘open loop-type’ wet scrubber, where the water is sourced and discharged from outside the system and the water flows only once through the unit. In a ‘closed loop-type’ wet scrubbers, water is reused after the scrubbing process in a continuous closed loop system. However, before the treatment water can be reuse for another SOx removal process in the unit, it must be clean to remove particulate matter and any other residues, and it must be treated to maintain its acidity (pH) value.

Regardless if the unit is open or close loop-type wet scrubber, both consists of same basic chemical process where alkaline liquid must be introduced in the treatment water to neutralise the acidic SOx based constituents. The unit works by dissolving water-soluble SOx gases contained in the exhaust gas by mixing it with the treatment water. To efficiently remove SOx from exhaust gas, it is crucial to maximise the surface area of the treatment water to be in contact with the exhaust gas. A larger surface area will promote better absorption of SOx by the treatment water.

The mixing process of exhaust gas with treatment water commonly takes place in a tower like structure that is fitted with spray nozzles. The unit may even be fitted with a cascading liquid system. This involves having the treatment water flowing downwards as the exhaust gas passes up through the scrubbing liquid cascading over the maze-like baffles, promoting mixing of the two streams. It is important to ensure that the wet scrubber unit does not excessively restrict the natural flow of the exhaust gas and exceeding the exhaust backpressure limits of the engine or boiler.

Open loop-type

In an open loop-type scrubber, seawater is used as the medium for cleaning the exhaust. Seawater reacts with SOx in the exhaust gas to product mainly sodium, but some calcium sulphate and sulphites may also be produced during the scrubbing process.

As highlighted earlier, an open loop-type scrubber is only effective if the treatment water is alkaline; which varies depending on the chemistry of seawater where the ship is in operation. In situations where the pH value of the water is too low (not alkaline), the scrubber unit will not reach its optimum performance level to work efficiently. When such a situation arises, ship-owners may need to use low sulphur fuel to comply with the 2020 low sulphur regulation. Furthermore, as there is no control over the alkaline level of seawater, an open loop scrubber unit will have significantly larger water flow rates compared to a closed loop unit. This is to ensure the effectiveness of the cleaning process when lower alkalinity water is used; hence more sea water is required.

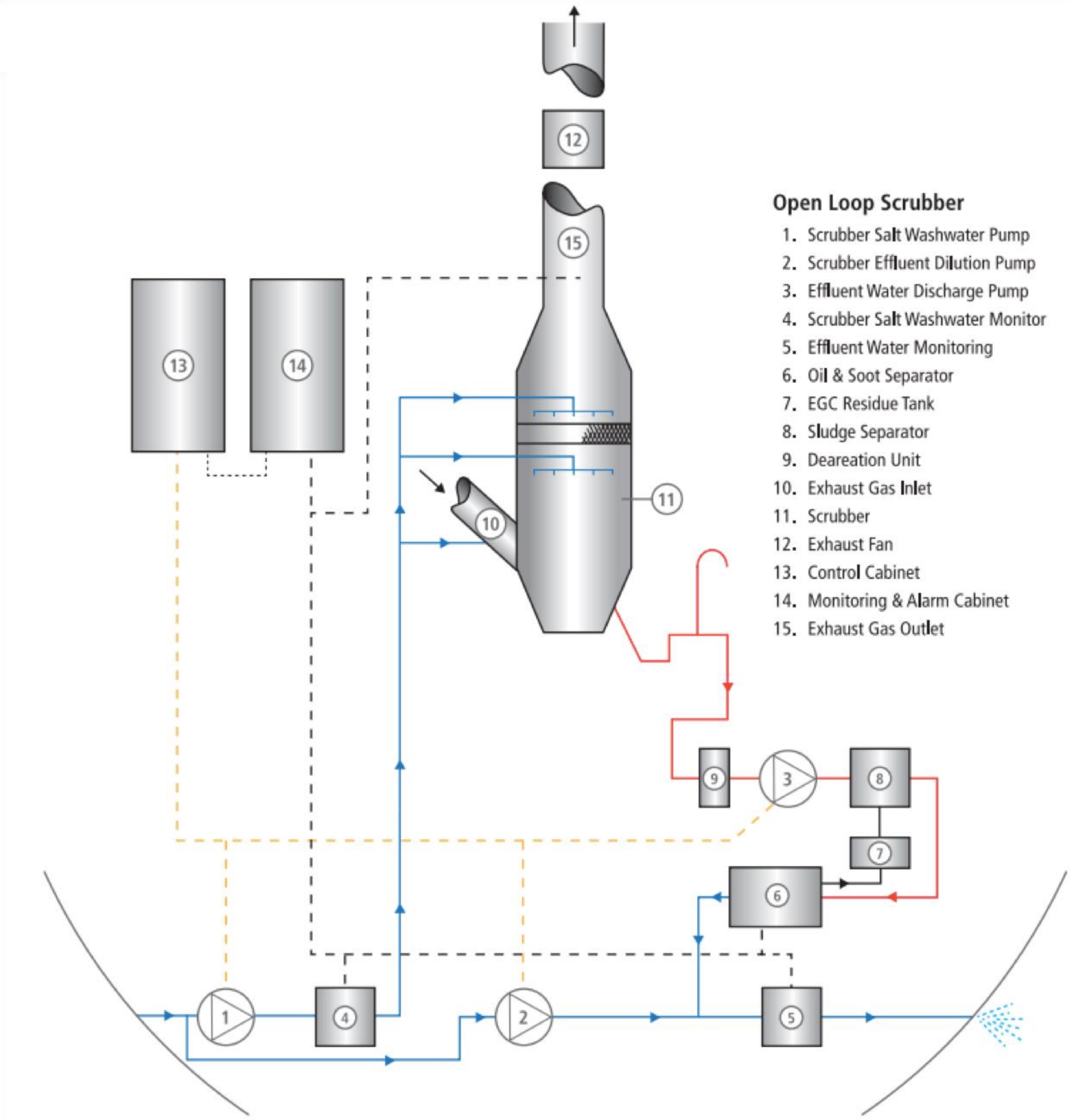


Figure 4-5 Schematic drawing of an open loop-type scrubber

Source: Tran 2017 p.5

After the main cleaning process has taken place in the unit, the exhaust mixture will then pass through a demister or water droplet separator. This process is necessary as it removes water particles from the gas, to reduce the potential for steam generation when the exhaust is released into the atmosphere. As for the wash water, which is the mixture of water generated during the scrubbing process, it will fall to a wet sump at the bottom of the scrubber unit. It is then removed from the sump either by gravity or a pump and taken through a separator to remove residuals from the wash water.

The residuals will contain particulate matter, ash and heavy metals that were removed from the fuel. It may also contain insoluble calcium sulphate and slit that flows in along with the wash water when drawn from estuaries or rivers. If the source of the wash water has a large amount of slit, the slit can make up the primary portion of the sludge volume. Sludge generated from residuals is only found in an open loop-type scrubber.

The residuals can only be discharged overboard once it has been removed from the wash water. In cases where discharge of such water is restricted, it must be retained onboard until it can be discharged to shore as a waste substance. As for the removed residuals, it will be stored in a dedicated residue tank onboard before being disposed of at a suitable reception facility ashore.

Closed loop-type

The internal layout and chemical process to remove SOx in a closed loop-type scrubber is like an open loop-type. The difference lies in the purpose of the wash water after the scrubbing process is completed; wash water is reused in a closed loop-type unit instead of being discharged overboard as seen in an open loop-type. As there is little to no water being discharged overboard after the scrubbing process, the need for wash water to be processed for safe discharge is eliminated.

Depending on the design, the wash water for the unit can either be fresh water or salt water. If fresh water is used, it will need to be treated by adding alkaline substances, usually sodium hydroxide, to control the level of alkalinity in the wash water. The chemical addictive can also be produced by electrolysis of seawater.

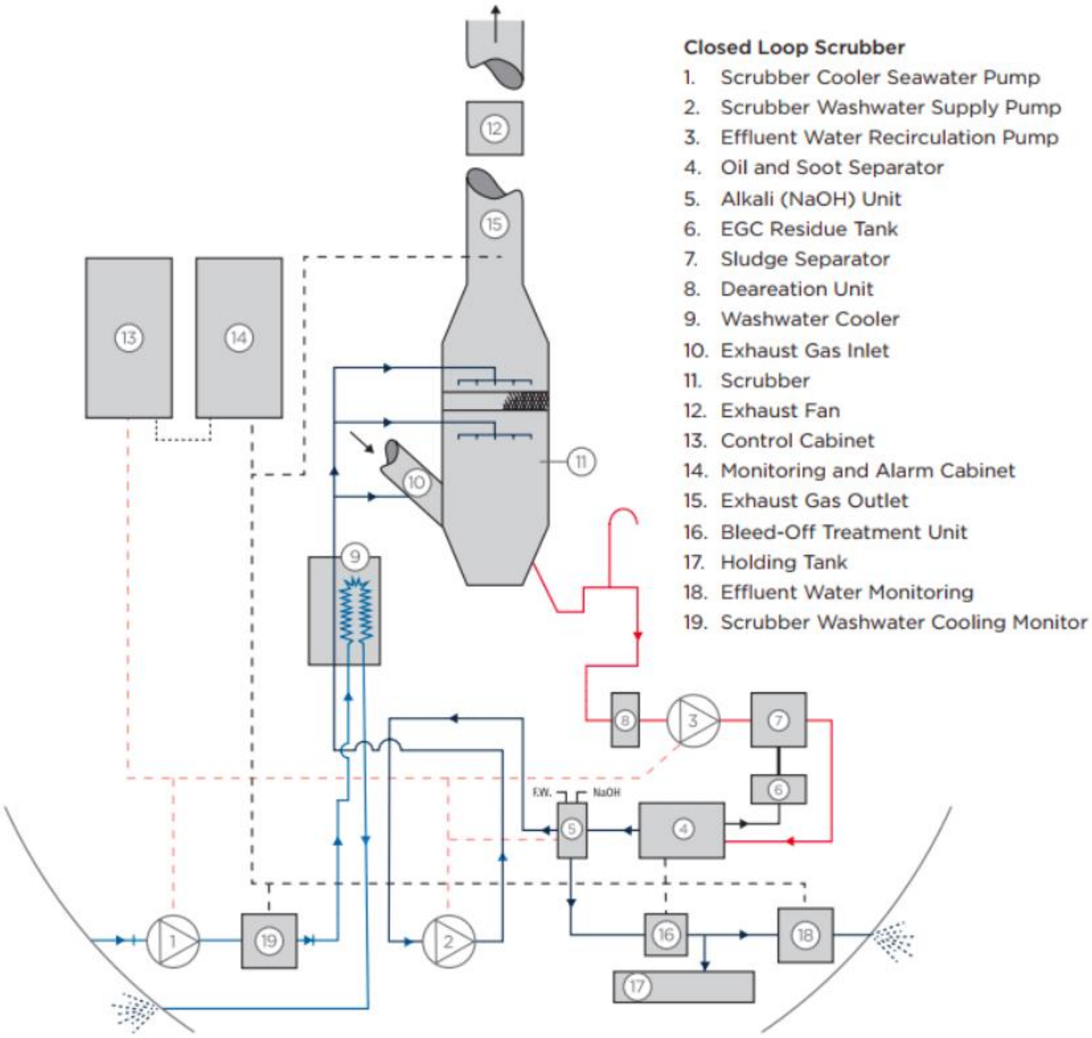


Figure 4-6 Schematic drawing of a closed loop-type scrubber

Source: Tran 2017 p.6

The treated water is then circulated through the unit. Scrubbing process in a closed loop-type unit works independently regardless of the chemistry of the waters the ship is sailing in (ABS, 2013). Once the scrubbing process is completed, the dirty wash water goes to the processing or circulating tank where it is treated to make it suitable for recirculation in the unit. This involves the removal of residues before caustic soda is added again to restore its alkalinity. Similar to an open loop-type unit, the residues are removed and stored until disposal ashore (ABS, 2013). More water is also added to the process tank to replace wash water that were lost during the treatment process and from evaporation during the scrubbing process. A pump is used to transfer the treated water back to the scrubber unit to be reused.

In a closed loop-type unit, the wash water required is only about half or less than the amount needed in the open loop-type scrubber to achieve the same scrubbing efficiency. This is due to high level of alkalinity is easily achieved in a closed loop-type scrubber, by having direct control of the alkalinity level through the chemical addictive injection process (ABS, 2013).

Hybrid scrubbers

Aside from open and closed loop-type scrubbers, some scrubber manufacturers are also developing a hybrid scrubbing system that utilises the advantages from both systems. The advantages in an open loop-type scrubber stems from not having to purchase and handle caustic soda and not having to process the wash water. As for a closed loop-type scrubber, the unit works with the same efficiency regardless of where the ship is in operation and having little to no water being discharged from the unit (ABS, 2013).

In a hybrid type scrubber, the system operates as an open loop system when the ship is in the open seas, and switches to a closed loop system when the ship is operating within designated ECAs. The changeover from open to closed loop is made possible by switching over the circulating pump suction from the seawater, to the fresh water circulating tank, and also changing the wash water discharge from the overboard discharge to the circulating tank (ABS, 2013).

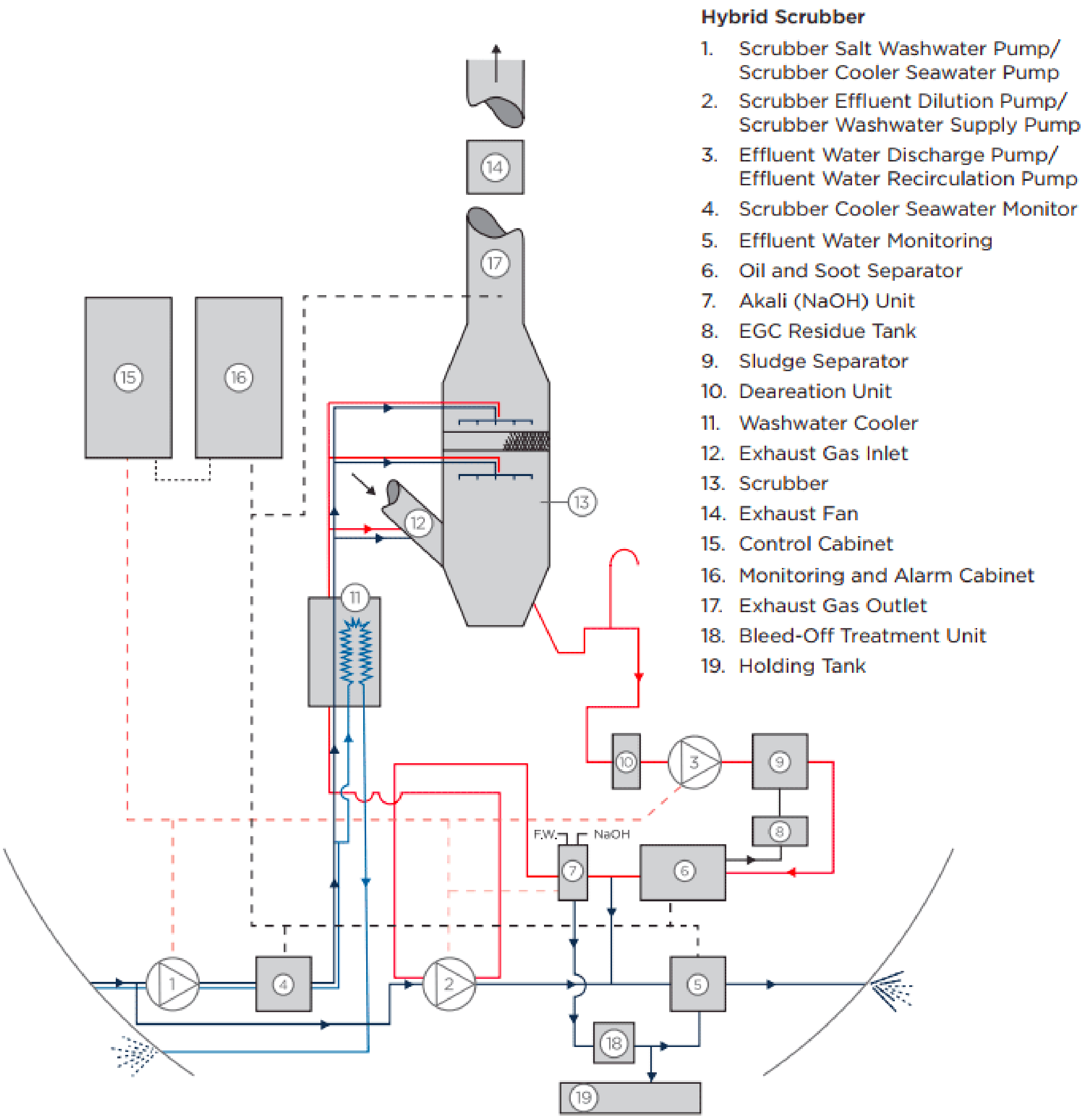


Figure 4-7 Schematic drawing of a hybrid type scrubber

Source: Tran 2017 p.6

The benefit of a hybrid system is that it provides ship-owners with the flexibility to operate the unit in low alkaline waters, as well as the open seas.

4.4.2.3 Membrane scrubbers

Like wet scrubber, membrane scrubbers also use a basic liquid absorbent, either salt water or ionic liquids, to react with the exhaust gas for removal of sulphur oxides. However, the difference from wet scrubber is that this system does not spray liquid absorbent directly into the exhaust stream to mix with the gas. Instead, the liquid absorbent is suspended in membranes to allow it to come into contact with the exhaust gas; without physically mixing both streams (Ionada, 2016). This way, only targeted gases are absorbed by the membrane and selectively removed from the exhaust stream.

Currently, *Ionada* is the first company worldwide to develop, manufacture and market these membrane exhaust gas cleaning system for the marine industry. Their patented membrane scrubber requires no chemicals and removes sulphur oxides using ionic capture technology. To maximise efficiency, nanotechnology hollow fibre porous membranes were used as the ideal contactor in the unit.

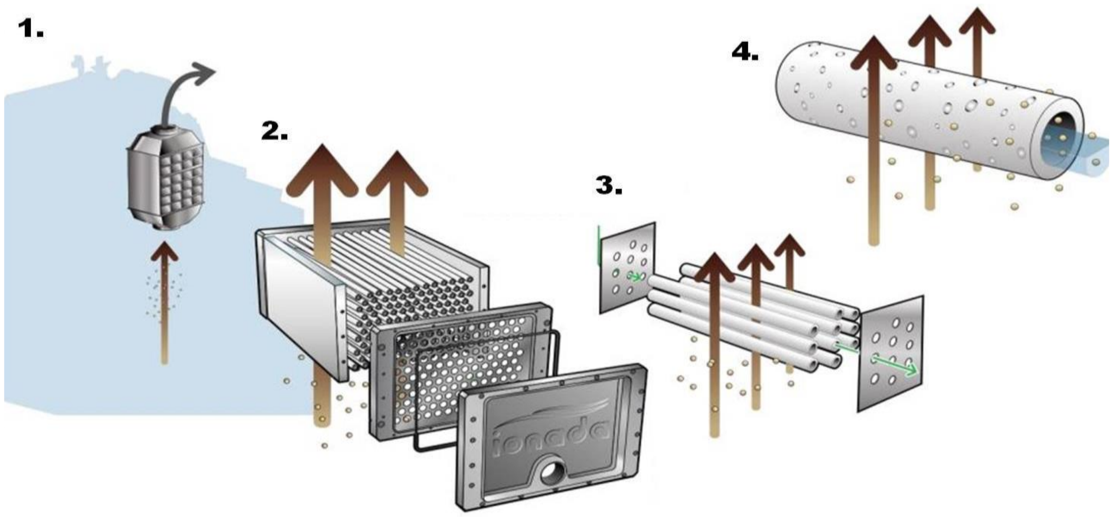


Figure 4-8 Ceramic membrane separation technology

Source: Carter and Panziera 2015 p.7

Based on **Figure 4-8**, Ionada's ceramic membrane separation technology works by (1) channelling the exhaust gas containing sulphur oxides to the membrane scrubber unit, where (2) sulphur oxides will be removed as the exhaust gas passes through the modular unit. The exhaust gas containing sulphur oxides will (3) be passing through numerous asymmetric porous ceramic hollow fibre tube membranes located within the modular unit, where (4) absorbent solution, such as ionic liquids, are flowing through the tubes for sulphur oxides to be captured by the solution.

The concept of using membrane technology is to selectively collect sulphur oxides from exhaust gas, while keeping the flue gasses separated from the absorption solution. This process eliminates spraying water (seawater or sodium hydroxide) directly in the exhaust path and eliminates the need for complex wash water separation process before it can be discharged. This is a major advantage of this system when comparing with wet scrubber technology, where significant amounts of sludge are generated.

In other words, there is zero wash water discharge, no sludge disposal fees and no pH discharge when using membrane scrubber. Based on a pilot test, it was confirmed that the system has successfully reduce sulphur levels in exhaust gas to well below the 0.1 percent sulphur limit (Panziera and Clarke, 2015). Not only does this comply with the 2020 global sulphur regulation of 0.5 percent limit, but it also means that ships plying in ECAs are able to adopt this technology onboard as it meets the 0.1 percent sulphur limits.

The membrane scrubber unit is also 30 percent more energy efficient as compared to other widely-available scrubber units. As the system does not require wash water, it allows the unit to be more than 50 percent smaller compared to other scrubber units, as it removes onboard chemical, waste or water storage requirements. Lastly, being modular and having a less complex configuration, eliminates the need to run piping system through engine room spacing, casings and back down to overboard discharges. Compared to wet scrubbers, this is a significant saving from not requiring hundreds of meters of piping passing through multiple decks to circulate water between the unit and the source of water. As such, this makes it easier and more cost effective to retrofit membrane scrubbers onboard. All these advantages will effectively translate into cost savings for ship-owners and ensuring that all regulations are met.

4.4.2.4 Economic feasibility of scrubbers

As covered, there are three different concept of scrubber units available to ship-owners to adopt on existing and new ships, depending on the machinery configuration, operational profile and the routes of the ship, such as time spent inside/outside areas and harbours with restrictions against wash water discharge (DNV-GL, 2016).

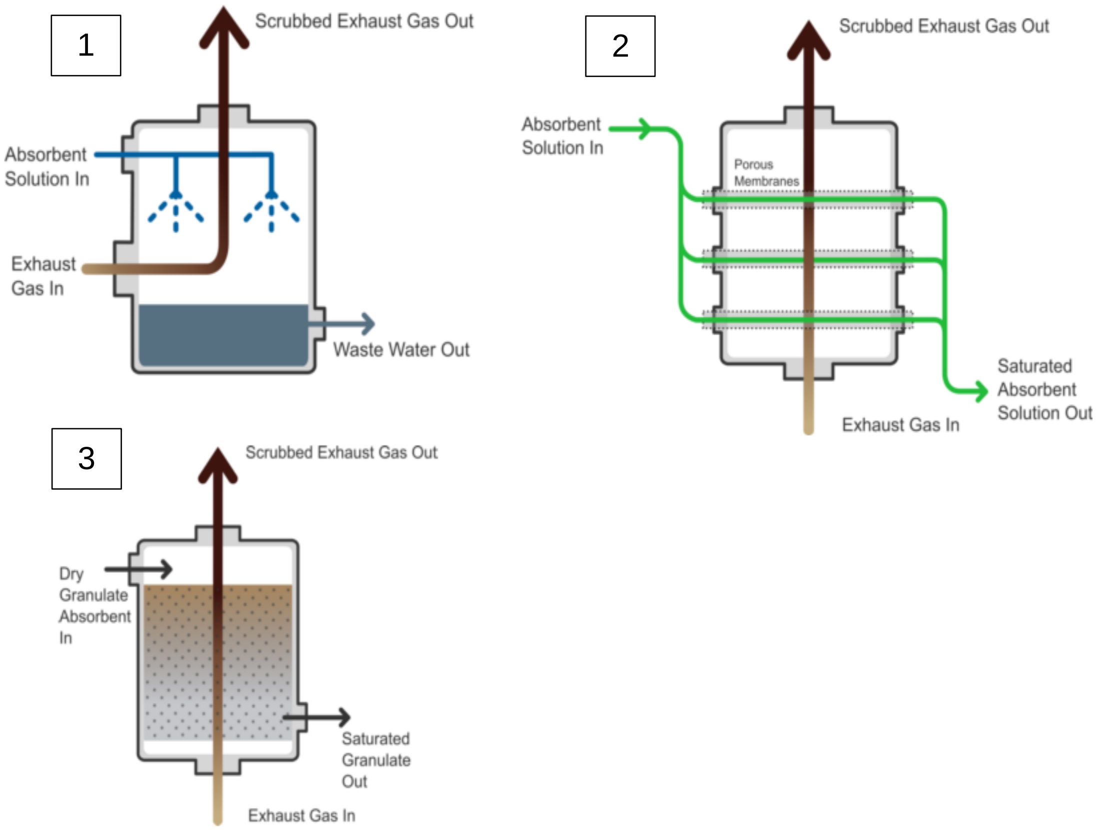


Figure 4-9 Types of scrubbers available in the market

(1. wet scrubber, 2. membrane scrubber and 3. dry scrubber)

Source: Carter and Panziera 2015 p.5

Once ship-owners have decided to install a scrubber system onboard, they must first determine the ship's operating pattern. This will have an influence on the type of scrubbers appropriate for the ship. If the ship has minimum port stay or transit time whilst in designated ECAs, or if there are no restrictions on water discharge by local or regional regulations, an open loop-type scrubber is considered appropriate. However, is the ship has to spend considerable amount of time whilst in port or transiting ECAs, a hybrid or closed loop-type scrubber system is then appropriate (ABS, 2013). As for membrane scrubbers, ship-owners can install them regardless of the ship's operating patterns and local conditions, as the system works independent of where the ship operates.

In addition, ship-owners must also consider all national or regional regulations that may be applicable with regards to using scrubber units onboard in lieu of using low sulphur fuels. As covered earlier in **Chapter 3.4.2**, the Council of the EU has adopted a directive amending directive 1999/32/EC regarding the sulphur content of marine fuel. One of the key elements in the directive is to allow for the use of alternative exhaust gas cleaning systems, such as scrubbers. Under the directive, the only type of scrubber systems allowed to be used on ships whilst trading within the EU is of the closed-loop type. As such, ship-owners must take this into consideration when determining the type of scrubber unit to be installed.

The main benefit of installing scrubber units onboard is that it allows ship-owners to continue burning high sulphur fuel oil from 2020, while still complying with the stricter 0.5 percent sulphur limit (Jordan and Hickin, 2017). It is up to individual ship-owners to justify the economic feasibility of installing a scrubber system for their ships. One of the ways is to consider the potential price spread between HFO and low sulphur fuels in 2020.

If ship-owners believe that HFO prices will plummet and the price of low sulphur fuels will climb as the demand shifts in 2020, the up-front capital cost of a scrubber system may appear as a practical and sensible investments for them. This will also be encouraging for the minority of ship-owners who had invested and retrofitted their ships with scrubber systems, as that initial capital is saved in terms of lower fuel bills; contributing to faster payback period. However, if there is significant increase in the uptake of scrubber technology by ship-owners, there is a high possibility that demand for HFO will be preserved. In that case, the price differential between HFO and low sulphur fuels may be narrower than expected. Ship-owners may therefore consider to either continue using HFO with scrubbers installed or switch to low sulphur fuels.

Aside from considering the long-term profitability of either operating the ship using low sulphur fuels or burning HFO with scrubbers, ship-owners must also consider the high costs associated with having scrubbers fitted onboard. According to Molloy (2016), it was estimated that initial cost for a scrubber unit can cost ship-owners somewhere between USD three to five million. On top of the unit cost, ship-owners must also pay for costs associated, but not limited to: the unit's installation process, additional miscellaneous auxiliary equipment and ship's modification.

Furthermore, the cost of additional fuel consumption required to operate the scrubber unit and the cost of consumables (where applicable), must also be factored in (ABS, 2013; DNV-GL, 2016). Not forgetting also, costs associated with the disposal of wash water used during the scrubbing process (DNV-GL, 2016; Makkonen and Repka, 2016). These costs have yet to include the cost of placing the ship on off-hire, and the cost of taking the ship to dry-docks for about a month, for installation process to be carried out (Jordan and Hickin, 2017). Based on these costs, it may be cheaper for ship-owners to incorporate scrubber systems on a new-build, than as an add-on or retrofit onto current ships (Molloy, 2016). These costs also make less financial sense for ship-owners to invest in scrubber systems for their ships that are nearing its operational life expectancy or are likely to be scrapped within a few years (Jordan and Hickin, 2017).

In addition, ship-owners also need to consider the availability of repair docks or dry-docks for the installation of scrubbers. The potential influx of ship-owners installing scrubber systems nearer to the implementation date of the low sulphur regulation in 2020, may result in these spaces to be limited due to the high demand. Spaces may also be limited as ship-owners are gradually retrofitting their ships with ballast water management systems to comply with new regulations (Jordan and Hickin, 2017).

It is undeniable that the use of scrubbers has provided ship-owners with a viable alternative solution to comply with the 2020 low sulphur regulation; that may even have significant operational cost saving benefits (ABS, 2013; Jalkanen *et al.*, 2013). However, opinions on the economic feasibility of a scrubber unit remains inconclusive, due to contrasting views on the subject matter. Furthermore, there is scarcity on independent literature available regarding economic feasibility of scrubber unit, making it difficult to comprehend the actual outcome.

In a study by Tzannatos (2011), it was found that the use of scrubber units was more cost-effective than using LSF for ship-owners to comply with sulphur regulations. However, it is not practical to apply that finding to current affairs, as data gathered and used during the study may be outdated and not applicable to current circumstances. This is specifically in relation to the data on the price of LSF, which fluctuates constantly based on market situations. As such, the price of LSF used in the study may be different to current market value; resulting in a different outcome from initial finding.

Although earlier literature mostly support economic feasibility of marine scrubber system (Mazraati, 2011), there are studies that indicate otherwise. This is evident based on a case study that was carried out on ships that uses scrubber units whilst operating in SECA. The study found that the use of alternative fuel – LNG, was the most financially attractive option to meet the stricter sulphur regulation (Nikopoulou *et al.*, 2013). Furthermore, a study by Yang *et al.* (2012) found that the 'changeover method' to control emissions of SOx is the preferred option by ship-owners. This method involves using segregated tank design where the ship switches to LSF from HFO when entering SECAs.

Aside from inconclusive opinions regarding economic feasibility of installing scrubber systems, it is also challenging to predict the rate at which scrubbers will be installed on ships towards 2020. In a report by Ensys Energy (2016), it is projected that *"a limited fraction of ships will be running with onboard scrubbers by end-2019"* (p.131). However, the International Energy Agency predicts that *"as 2020 approaches, and forward curves better reflect reality, … there will undoubtedly be an increase in scrubber installation"* (IEA, 2016, p.39).

According to Makkonen and Repka (2016), one of the reasons ship-owners are not installing scrubber systems on their fleet was because of the high costs involved. But looking back at the trend before the 0.1 percent SOx limits took effect in SECAs on 1 January 2015, there was an increase in demand for scrubber units according to industrial books. As such, there is a possibility that this trend may also be seen in the 2020 global sulphur cap regulation. Some ship-owners may also be hoping for scrubber installation prices to drop as more manufacturers enter the market (Jordan and Hickin, 2017).

4.4.3 Solar

Lastly, in terms of technological solutions, ship-owners may also have the option of installing solar onboard to comply with the 2020 low sulphur regulation. Solar propulsion technology is an upcoming innovative solution being developed in the marine equipment sector.

Over the years, there have been significant advances in research and development for more effective lightweight solar panels suitable for the marine environment (RINA, 2017). Advances in solar cell and photovoltaic module technologies, have contributed to solar power becoming a cost-effective fuel reduction option for owners of pleasure boats, ferries and tourist vessels (EMP, 2017). This technology was successfully installed on motor ship *Turanor PlanetSolar*. The solar-powered craft was fitted with 127 photovoltaic panels covering 537 square meters and have a maximum speed of 14 knots (Ship Technology, 2017). The combination of solar power with batteries have also been successfully installed on several small commercial ships (Rutkowski, 2016)

Currently, it is unfeasible to use solar panels alone to provide the required levels of energy needed to propel a large commercial ship (RINA, 2017). Furthermore, the amount of fuel saved on large ships through the use of solar power alone is relatively small (Atkinson, 2011). This meant that ships are still required to burn large amounts of fuel for propulsion; thus, still emitting significant amount of harmful pollutants. The only advantage solar technology can provide to ship-owners currently is that, the power generated can be used as an important alternative source of energy for onboard electrical systems. This helps to reduce the ship's overall fuel consumption and emissions (RINA, 2017).

The first ship to direct solar power into the main electrical grid onboard is motor vessel *Auriga Leader*. The car carrier ship-type had an array of solar panels installed as part of a demonstration project organised by the Port of Long Beach, Toyota and Tokyo-based shipping company, *NYK Line* (White, 2009). The focus of the project was to reduce ship's dependency on diesel, as the fuel emits significant amount of harmful emissions even when ships are docked and undergoing cargo operations at port. The ship was fitted with 328 solar panels. Energy harvested from these panels were used to power the ship's thrusters, hydraulics and steering gear. This amounted to approximately 10 percent of the ship's total electricity usage that was provided by the solar panels.

Another approach to maximise the level of energy required to propel a large commercial ship, is to design a system that taps into the power of both wind and sun. This system, developed by Eco Marine Power, is called the *Aquarius MRE* which combines sail power (using rigid sails) with solar power. This patented system overcomes the practical limitations of using rigid sails and solar panels on ships.

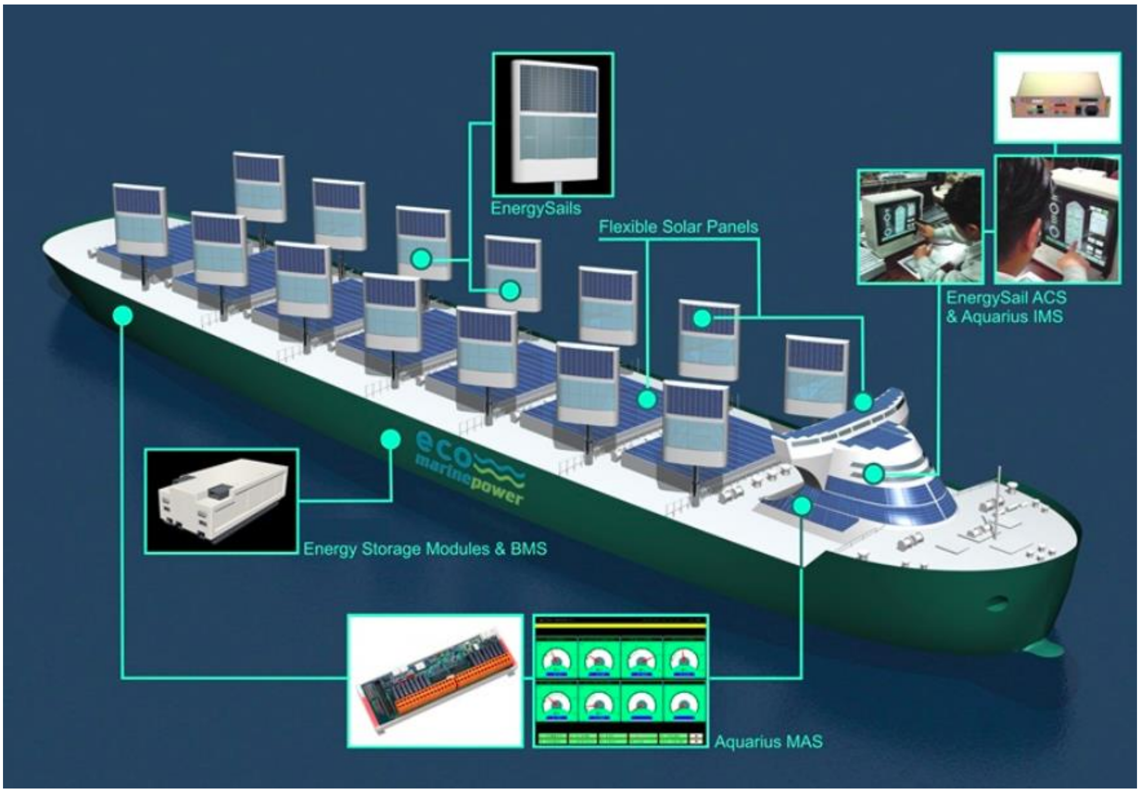


Figure 4-10 Wind and solar power concept ship

Source: Atkinson 2011 p.1

The solar power array, which can either be mounted on the sails or on the deck areas of the ship (or both). These panels will in turn charge batteries, or the power can be fed into the direct current or alternating current power distribution system. In addition, the energy stored in the batteries can also be used as a source of emergency or back-up power system (Atkinson, 2011).

By harvesting energy from both the wind and the sun as a source of energy for ship's propulsion (in addition to the ship's main engine), the 'hybrid powered' ship is able lower ship's harmful emissions and fuel consumption. The company behind the technology is offering potential customers with an attractive return on investment proposition. Combined with the environmental benefits, this hybrid marine power technology has the advantage of gaining widespread acceptance across the maritime industry (Atkinson, 2011).

The system has been installed on the *Aquarius Eco Ship*, a bulk cargo variation ship-type. This is a concept ship that was constructed with focus on *"optimising the design of a large ocean-going ship such as a bulk carrier, oil tanker, roll-on/roll-off vessel or cruise ship, to harness the power of the wind and sun using Aquarius MRE"* (Atkinson, 2018, p.1). The eco-ship is expected to result in fuel savings of 40 percent or more, in addition to significantly reducing the emission of noxious gases such as SOx and NOx. The system can be easily integrated into a new ship design or retrofitted to ships already in service.

Although there is insufficient data available on the economic feasibility of this system, in addition to the lack of commercial ships that are fitted with the system onboard, this technology can be adopted by ship-owners to comply with the 2020 low sulphur regulation.

4.5 Barriers to implementation of technological solutions

Referring to **Chapter 2.4.2**, one of the barriers to product innovation identified from available literatures is related to low market and customer demand. In other words, manufacturing companies were not innovating due to the lack of demand for innovative products in the market. As such, it is important to investigate the reasons behind the weak market demand for technological products. This information contributes to the understanding of why low market and customer demand acts as a barrier to product innovation. Equipment manufacturing companies stands to benefit from this information as it allows them to find solutions to overcome the barriers; thus, potentially resulting in an increase in the uptake of technological products by ship-owners.

Based on a survey conducted on ship-owners, Rehmatulla (2015) has identified several barriers to implementation of technological products onboard. These barriers are related to: payback period of investment, access to capital and lack of information. Other barriers also include potential changes in regulations (Ship and bunker, 2018).

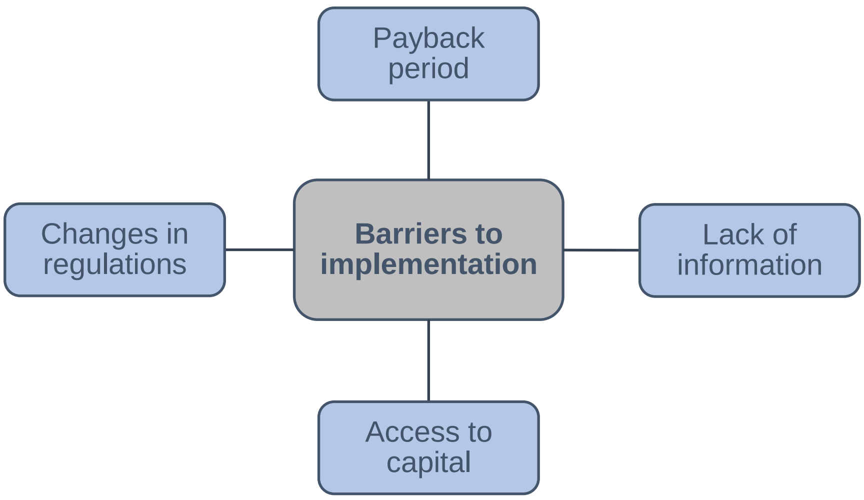


Figure 4-11 Barriers to implementation of technological solutions

Source: Author's own 2019

Payback period is one of the main tools often used by ship-owners as an investment appraisal instrument. Therefore, in cases where the payback period for an investment is long, ship-owners avoid adopting that technological product for their ships. This is due to the investment not being financially viable for ship-owners. Ship's age also plays a crucial role in the payback period of the investment, as ship-owners are not able to justify investing in a product with a payback period of between three to five years when their ship is nearing its operational life expectancy. Furthermore, market factors such as low earnings and lower fuel prices are also potential reason for the lack of implementation, as *"low fuel prices have an adverse effect on the payback of* [technological products]*"* (Rehmatulla, 2015, p.10).

Access to capital is another barrier to implementation for ship-owners, considering technological products are capital intensive that requires ship-owners to *"finance them through their balance sheet or have access to favourable borrowing"* (Rehmatulla, 2015, p.11). With traditional shipping banks decreasing their loan books and few are willing to participate in retrofit finance, ship-owners find it challenging to implement expensive technological products onboard. As such, cost constraints prevent ship-owners from investing any capital for technological products.

Lack of information is another key barrier to implementation of technological products onboard by ship-owners (Smith *et al.*, 2014). This is in relation to the availability of reliable information on costs and savings of a technology. According to Rehmatulla (2015), the lack of information stems from *"shortage of publicly available, detailed and transparent data, bespoke and non-standardised measurement techniques, high degree of operational specificity (ship-types and sizes) and wide variability in day to day performance"* (p.11). As such, any claims made by manufacturers on their technological products, are treated with utmost caution and may even be perceived as misleading by ship-owners. It is therefore crucial that ship-owners are provided with the necessary information and evidence of a product's reliability to guarantee the claims made.

Lastly, barriers may also come in the form of potential changes in regulations. According to Cameron Mackey, Chief Operating Officer of Scorpio Bulkers incorporation, *"it is only a matter of time before regulators revisit the scrubber solution and realise that a scrubber takes emissions and instead of putting them into air, actually puts them into the sea"* (as cited in Ship and bunker, 2018, p.1). Ship-owners are *"naturally quite sceptical that the regulations* [do not] *change"* (Ship and bunker, 2018, p.1). As such, potential changes not only to the implementation of the 2020 low sulphur regulation but also around scrubber technology itself, acts as a barrier to implementation.

Furthermore, there may well be other barriers to implementation faced by ship-owners. But the lack of available literatures on the barriers, especially in relation to meeting the 2020 low sulphur regulation, means this list is not exhaustive.

4.6 Summary

To summarise, the marine equipment sector plays a significant role in helping the shipping industry meet the global sulphur regulation. This is because apart from alternative fuels such as LNG and LSF, ship-owners can also adopt technological products supplied by the marine equipment sector, especially scrubber systems, to comply with the regulation.

However, ship-owners may not be in a rush to adopt technological solutions for their ships as IMO regulations have yet to be enforced. Furthermore, low profit margins faced by ship-owners also meant that they do not have the required funds to retrofit their fleet with such systems (EC, 2013b). As such, the decision whether to switch to burning LSF or to install scrubbers onboard, will be a tough decision for ship-owners to make.

Ship-owners will have to conduct a cost-benefit analysis to help determine which solution will be better for their business overall: to either use LSF or to continue burning HFO with scrubber units. This involves considering the cost of scrubber systems, which is in the upwards of several million pounds, and the potential loss in revenue and income from having to place the ship on off-hire for installation process. Ship-owners must also consider the challenges involved with adopting scrubbers, such as access to finance and the payback period for their investment.

CHAPTER 5 CONCEPTUAL FRAMEWORK

5.1 Introduction

In any research, it is important to have a conceptual framework as it can be used to guide the research. The framework is based on concepts drawn up from various theories and research findings that were used in the research. It helps the researcher to set out the scope of the existing literature and to have a comprehensive understanding of the phenomenon that is being researched. The use of conceptual framework is part of the research process, which is relatively obscure amongst the multitude of research literature available (Green, 2014). As such, conceptual framework is there to assist the researcher to ensure that their research project has coherence, and to focus their mind on what the research aims to achieve.

The next part of this chapter presents the conceptual framework that was developed, based on concepts that were identified and extracted from earlier chapters. The framework provides a systematic overview of this research and allows the researcher to identify the research gaps, in which this research aims to answer. A summary of this chapter is then provided.

5.2 Conceptual framework

As stated in **Chapter 1**, this research is concerned with discovering the variables that drive innovation in the marine equipment sector within the EU, with the aim of applying this knowledge within the European institutional framework for cleaner air. Innovation here, refers to technological products that are available to ship-owners to adopt on their ships, to comply with air pollution regulations.

The regulatory framework that guides this research is based on the information gathered in **Chapter 3.7**, on air quality regulation and policy of the EU and the

IMO, in relation to atmospheric emissions from shipping. The regulation sets limits on sulphur oxides and nitrogen oxides emissions from ship exhaust, as well as particulate matter, that is coming into force on 1 January 2020. The regulation is found under IMO MARPOL Annex VI and EU Sulphur Directive 2012/33/EU.

Ships are also subjected to the energy efficiency regulation under Chapter 4 of MARPOL Annex VI, where the EEDI and SEEMP were made. The EEDI is aimed at promoting the use of more energy efficient (less polluting) equipment and engines, while the SEEMP is an operational measure used to improve the energy efficiency of ships in a cost-effective manner. Under EU regulations, ships calling at EU ports are further subjected to the MRV regulation. This additional step taken by the EU is to further cut CO2 emissions from maritime transport.

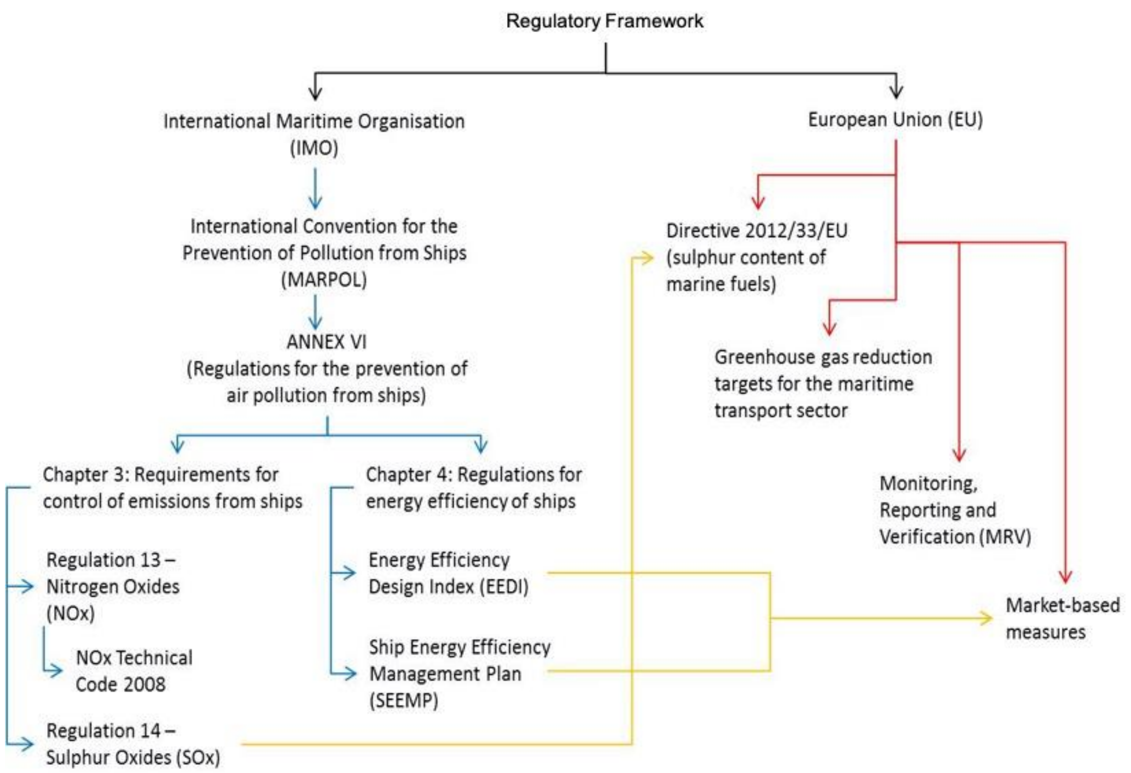


Figure 5-1 Regulatory framework of the IMO and the EU

Source: Author’s own 2019

The regulations (in this case, the “cause”) brought about by the IMO and the EU, has an impact on the EU’s marine equipment sector and on ship-owners (the “effect”). This “cause and effect” relationship exists as ship-owners need to adhere to the rules and regulations set by governing bodies; where any changes made to the regulations will consequently have an impact on their operations.

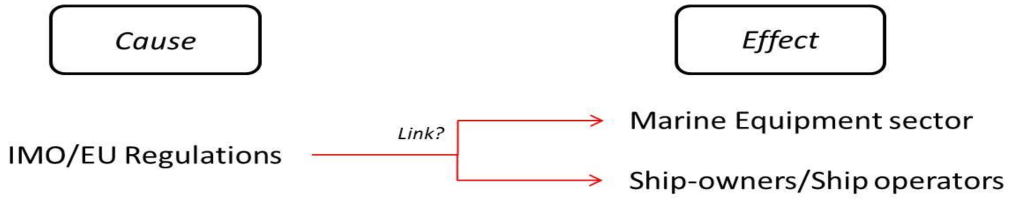


Figure 5-2 “Cause and effect” of IMO and EU regulations

Source: Author’s own 2019

The EU’s marine equipment sector in this instance, is also affected by changes made by governing bodies on the low sulphur regulation. This is because, the sector now needs to develop new innovative technological solutions for ship-owners to comply with the new regulation. Not only is the marine equipment sector able to develop technological solutions to meet the new regulation, but the sector is also able to continuously promote innovation in innovative technology and equipment to meet EU’s potential of further reducing global emissions that harms humans and the environment. According to Lister (2014), innovative marine equipment are needed as part of the solution to curb pollution.

Ship-owners have until 1 January 2020 to be in compliance with the global low sulphur regulation. The options available to ship-owners are to either opt for alternative fuels, or to adopt technological products on their ships. As covered in **Chapter 4.3**, alternative fuels ship-owners can switch to include low-sulphur fuel, liquefied natural gas, methanol and biofuels. Conversely, ship-owners are also able to adopt technological products such as scrubber systems for their ships.

This system allows ship-owners to continue burning high sulphur content bunker fuel, while still being in compliance with the low sulphur regulation. Other technological products identified in **Chapter 4.4** that are available to ship-owners to implement to meet the sulphur regulation include: Flettner Rotors or SkySails that harvest energy from the wind to propel ships, and solar panels that harvest energy from the sun. These technological products also have the added advantage of significantly reducing the amount of CO2 emitted by ships.

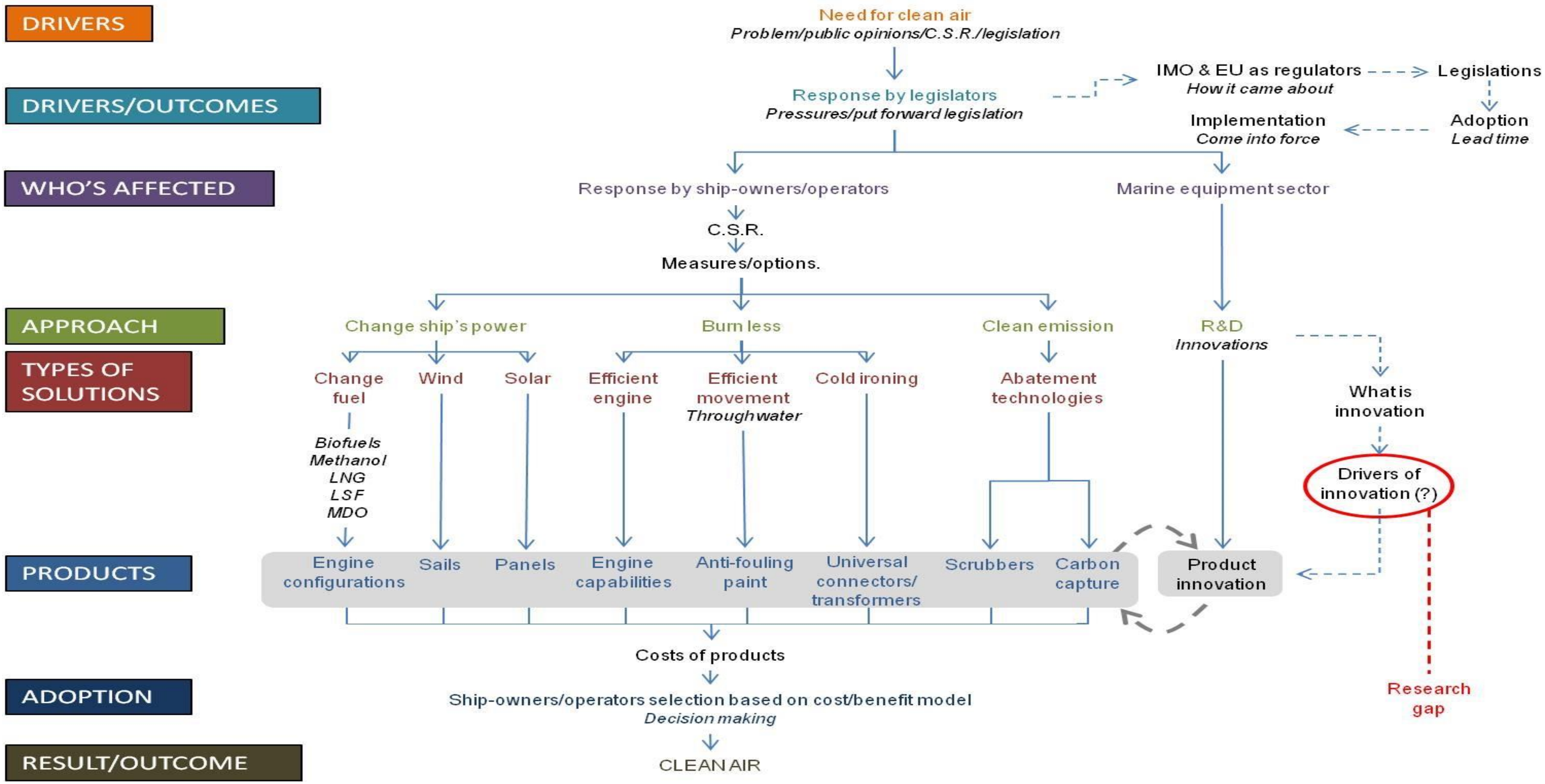


Figure 5-3 Conceptual framework

Source: Author's own 2019

5.3 Research gap

The conceptual framework for this research, as seen in **Figure 5-3**, has been developed through the literature review. The research gap lies in the variables that encourage or restrict innovation, which this research aims to identify. This is specific to the EU's marine equipment sector, in relation to innovative products to meet the 2020 low sulphur regulation. Previous studies of manufacturing in Germany and the EU (Lohmuller, 2004; Horbach *et al.*, 2012; Ghisetti *et al.*, 2017), have identified the variables that encourage or restrict product innovation. However, these identified variables are generic in nature. In other words, the variables may or may not be relevant or applicable to all industries. As the identified variables are not specific to the maritime sector, and to the marine equipment sector in the EU, there is a research gap that needs to be fulfilled.

It is also important to establish a link between regulation and innovations in the marine equipment sector, as it have been claimed by Makkonen and Repka (2016) that regulatory and commercial measures taken by the IMO have spurred the development of green ship technology. As the *"impact of regulation on innovation is an empirical, case-by-case question"* (Pelkmans and Renda, 2014, p.7), findings from studies which demonstrate that regulation promotes innovation (Casper and Matraves, 2003; Lee *et al.*, 2004; Shi *et al.*, 2016) cannot be applied to the shipping industry, which has unique characteristics as explained in Chapter 1. As such, it is important to investigate the impact regulation has on innovation in the shipping industry. This will consequently answer one of the aims of this study: *"… identify knowledge gaps between institutional policy and regulation …".* This information can then be used to encourage more innovations within the sector, whilst also determining the roles governments and institutional bodies can play in supporting this.

Based on the barriers to implementation of technological products by ship-owners (covered in **Chapter 4.5**), it is also important to investigate the link between the barriers and the level of innovation in manufacturing companies. This will highlight whether demand from ship-owners is one of the drivers of innovation. Finally, identifying the variables that restrict innovation in the marine equipment sector allows the researcher to suggest and make recommendations on overcoming the barriers. This may be in the form of support from financial institutions and governments (as covered in **Chapter 2.4.2**) that is crucial to encourage innovation in green ship technology. In the absence of institutional climates and frameworks, there is a possibility of shortages on the availability of new innovations and technologies that could have contributed to the reduction or prevention of pollution from ships (OECD, 2013).

5.4 Summary

The development of the conceptual framework has significantly assisted the researcher in organising the way the data were represented. The existence of the conceptual framework benefits the research in ensuring that it was given order and achieved completion in a way that could clearly be communicated to its readers.

Having developed the conceptual framework and realising the direction this research undertakes, the systematic and theoretical analysis of the methods being applied to this field of study is covered in the next section. The methodology comprises of the theoretical analysis of the body of methods and principles associated with a branch of knowledge.

CHAPTER 6 METHODOLOGY

6.1 Introduction

This chapter presents the research methodology, detailing the specific procedures and techniques that were used to identify, select, process and analyse information in this research. The chapter starts by looking at the different research paradigms available, before justifying the selected paradigm used to guide this research. Based on the selected research paradigm, the approach (or strategy) used in this study is then presented and justified.

In the following sections of this chapter, comparisons of the various research methods and their appropriateness, together with their advantages and disadvantages, were examined. Evaluation of the research in terms of its validity and reliability were then covered, before a brief discussion of research ethics is presented. Finally, this chapter concludes with a summary.

6.2 Research paradigms

A research paradigm is an interpretive framework or a basic set of beliefs that guides how scientific research should be conducted (Denzin and Lincoln, 2011; Collis and Hussey, 2014). The paradigms transcend from the basic ontological (the nature of reality) and epistemological (the means and conditions for knowledge) positions and they help classify different research approaches.

6.2.1 Positivist

According to Remenyi *et al*. (1998), positivism involves *“working with an observable social reality and that the end product of such research can be law-like generalisations similar to those produced by the physical and natural scientists”* (p.32). Essentially, this involves testing of hypothesis developed from pre-existing theory, which leads positivism to support deductive (not inductive) reasoning.

Positivism recognises reality as being objective (external and independent existence of social world). This enables knowledge to be obtained through observation and measurement of social phenomena, which can eventually lead to generalisations (Sarantakos, 2013). Positivism relies on quantitative methods such as questionnaires, statistical analysis and experiments to obtain the necessary knowledge (Blaikie, 2007; Eriksson and Kovalainen, 2008; Saunders *et al.*, 2009). As a result, positivism is often considered to be identical to quantitative methodology, due to its ontological and epistemological descriptions which dictate how this methodology should conduct research (Sarantakos, 2013). The fundamentals of positivism are reflected in the ontological and epistemological prescriptions, as well as in the theoretical background of quantitative methodology.

6.2.2 Interpretivist

Qualitative method of data collection is rooted in interpretive methodological principles, which provide a detailed description of events, situations and interaction between people and things that are related to the phenomenon under revision (Cooper and Schindler, 2008; Saunders *et al.*, 2009; Bryman and Bell, 2011). It enables researchers to explore and examine deeply into attitudes, and provides an understanding of a given context, underlying motivations and values through detailed descriptions (Ghauri and Gronhaug, 2010; Denzin and Lincoln, 2011).

Based on the ontological assumption (the nature of reality), interpretivist argue that the social reality is simply too complicated to be understood within a set of rules that lead to generalisations (Collis and Hussey, 2014). Therefore, epistemologically, interpretivist advocate for the need of the researcher to understand the differences between humans and social actors. Generally, the understanding is that humans play a part in the social world and as such, they interpret their social roles based on the meaning given to their roles (Denzin and Lincoln, 2011). This then means that from an interpretivist perspective, there are multiple realities of the social world (Collis and Hussey, 2014).

In this respect, the understanding of knowledge is often from each individual's own interpretation of the realities they are encountering based on their experiences; hence, making it an inductive or theory building in nature (Hatch and Cunliffe 2013). From this perspective, there is no generalisation as the focus is on what each person thinks or feels and how they communicate; therefore, this is often associated with the qualitative method of data collection (Easterby-Smith *et al.*, 2008; Saunders *et al.*, 2009).

6.2.3 Realist

Realism is based on the doctrine that reality exists independent of the human mind (Sarantakos, 2013). There are many types of realism introduced by scholars in a variety of academic research such as critical realism, direct realism, empirical or scientific realism and representative realism (Sarantakos, 2013). Realism can be seen to be in line with positivism, to the extent that it assumes a scientific approach to the development of knowledge, but it is less deterministic than positivism.

Realism is also derived from interpretivism, where even though it is concerned with the existence of things and how they behave, it also acknowledges that things may just exist without science or observation (Blaikie, 2007). Therefore, while realists object the interpretivist stand where social reality is pre-interpreted, it also agrees with the notion of positivism where science should be empirically based with clear rationale and objectives, rather than mere reliance on language or disclosure (Blaikie, 2007).

Hatch and Cunliffe (2013) states that with realism, reality appears in stratified form, where surface events are shaped by underlying events and what is observed is only partial than complete. On the other hand, Bhaskar (1989) states that we can identify what we do not see through practical and theoretical processes of social sciences. Therefore, to enrich knowledge acquisition and understanding, realism encourages research to be undertaken from multiple perspectives. As such, realism is often seen to support inductive reasoning or theory building.

6.2.4 Social constructionism

Social constructionism is a relativist epistemological position that is based on the notion of the social world being constructed by individuals through their social practices, rather than as a fixed entity, external to individuals and impacting on them in a deterministic way (Cohen *et al.*, 2004; Symon and Cassell, 2004). This is in line with Weick's (1995) argument, where people are part of their own environments and that it is through their actions that they contribute to the creation of *"the materials that become the constraints and opportunities they face"* (p.31). Socially constructed reality is therefore, seen as a continuous and active process where reality is continuously reproduced by individuals acting upon their representations of it.

Cromby and Nightingale (1999) states that under social constructionism, each individual and the world around them are the products of social processes. In other words, the values, practices and structures of meaning that constitute them are considered socially made. Taking the example of race, from a social constructionist point of view, it is considered as socially constructed rather than biologically determined (Siegel, 2006). Race construction starts with individuals being allocated to a socially agreed race category, which is determined by the colour of their skin at birth. Following this assignment, people treat those in one race category differently from those in the other, and children behave differently in response to this differential treatment (Siegel, 2006).

Social constructionism paradigm can be explained in relation to four key assumptions as outlined by Burr (1995):

1. <u>A critical stance toward taken-for-granted knowledge</u>

Constructionist challenge to notions of reality as objective, fixed and with the right instruments, knowable. This meant that social constructionism is an invitation for individuals to challenge orthodox understandings and to understand the processes by which such understanding was ‘natural’ or ‘true’. This challenge requires reflexivity in the research relationship.

2. <u>Historical and cultural specificity of knowledge</u>

Social constructionism implies that individual’s understanding of the world must be seen as historically and culturally situated and changing across time and space, and not be seen as static or inevitable (Young and Audrey, 2004).

3. <u>Construction of knowledge is a negotiated process</u>

Social constructionism is a negotiated process where certain interpretations are privileged over others. In everyday lives, individuals create and recreate versions of reality through social practice. While all constructions claim to be factual, some constructions are likely to be ‘true’. For example, natural events such as an earthquake are likely to be construed in terms of science, rather than religion in most parts of the world, although it is likely that some may interpret an earthquake as part of God’s doings.

Practical conditions of life are seen to provide a suitable climate for common-sense views prevailing at any one time. However, once these views become available culturally, they may be used by influential groups to advocate their interests (Burr, 2003).

4. Knowledge and social action go together

Social constructionism states that knowledge and social action go together, where prevailing versions of events give rise to certain actions and marginalises alternative ones (Burr, 2003). As Gergen (1996) suggests, *“it is the individual as socially constructed that finally informs people’s patterns of action”* (p.146). Therefore, dominant knowledge clearly has implications on what individuals can and should do. However, it is not often that individuals see their actions being influenced by dominant meanings or acknowledge the existence of alternative meanings. As stated by Burr (2003), dominant meanings are firmly entangled with social practices and over time, they become objective realities to individuals who experience them as such, in the course of their socialisation.

Based on the different research paradigms as discussed above, it was found that the positivist approach was not applicable or relevant for this research. This is due to the positivist approach not supporting theory building, where this research is inductive in nature (explained further in the next section). In addition, the use of statistical analysis and experiments were not appropriate measures to gather data for this research; thus, further rendering positivist approach as invalid for this research. With that in consideration, social constructionism, which views knowledge and truth to be created and not discovered by the mind (Schwandt, 2003), was employed to guide this research.

Social constructionism also supports the view that being a realist is consistent with being a constructionist. One can believe that ideas are constructed rather than discovered, and yet maintain that they relate to something real in the world. This is consistent with the idea of Luckmann and Berger (1991) and the subtle realism of Hammersley (1991), where reality is socially defined but this reality refers to the subjective experiences of daily life and how the world is understood, rather than the objective reality of the natural world.

6.3 Research approach

Another important element of research methodology is the research approach. Research approach directly effects the choice of specific research methods and can be divided into two types: deductive and inductive.

<u>Deductive research approach</u>

According to Wilson (2010), a deductive approach is concerned with *"developing a hypothesis (or hypotheses) based on existing theory, and then designing a research strategy to test the hypothesis"* (p.7). It involves confirming or rejecting a set of hypotheses or theories that has been formulated for the research. Babbie (2010) states that deduction starts with an expected pattern *"that is tested against observations, whereas induction begins with observations and seeks to find a pattern within them"* (p.52).

Researchers employing deductive approach in a study, starts by formulating a set of hypotheses. Following that, relevant research methods were chosen and applied to test the hypotheses. This is used to prove whether the hypotheses are either right or wrong. As such, deductive research follows the process as seen in **Figure 6-1**:

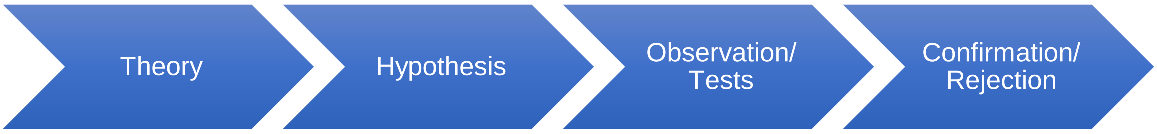


Figure 6-1 Deductive research process

Source: Author's own 2019

<u>Inductive research approach</u>

According to Bernard (2011), inductive approach *"involves the search for pattern from observation, and the development of explanations – theories – for those patterns through series of hypotheses"* (p.7). As such, inductive approach does not involve formulation of hypotheses or theories at the beginning of the research. It starts with research question and aims and objectives that need to be achieved at the end of the research process (Goddard and Melville, 2004).

It is important to highlight that this approach does not imply theories are disregarded when formulating research questions and objectives. What it aims to do is to generate meanings from data set collected, where patterns and relationships are identified to build a theory. Saunders *et al.* (2009) also state that this approach does not prevent researchers from using existing theory to formulate the research question to be observed. This approach is based on learning from experience, where patterns are observed to reach conclusions or generating theory. Furthermore, the researcher can change the direction of the study after the research process had begun.

According to Lodico *et al.* (2010), the approach is often referred to as a 'bottom-up' approach to knowing. This is where the researcher *"uses observations to build* *an abstraction, or to describe a picture of the phenomenon that is being studied"* (Lodico *et al.*, 2010, p.10). As such, inductive research follows the process seen in **Figure 6-2**.

Figure 6-2 Inductive research process

Source: Author's own 2019

The main distinctive point between the two approaches is on the relevance of hypotheses to the study. Deductive approach involves the formulation of hypotheses and their subjection to testing its validity during the research process. It can be described as *"reasoning from the general to the particular"* (Pellissier, 2008, p.3). Inductive approach on the other hand, contributes to the emergence of new theories and generalisations. This approach does not deal with hypothesis in any ways. Application of inductive approach is generally associated with qualitative methods of data collection and data analysis, whereas deductive approach is related to quantitative methods.

As this research aims to gain a rich and complex understanding of the research topic, an inductive approach is employed. Inductive approach allows the researcher to generate meanings from the data set collected, to identify patterns and relationships to build a theory. Therefore, the deductive approach is rejected as this research is not aiming to achieve its research objectives by testing hypotheses.

6.4 Research methods

In any research undertaken, the choice of research method is guided by the ontological or epistemological position taken by the researcher. However, there are two methods of research often discussed in literature and these are the qualitative and quantitative methods. According to Jick (1979) and Patton (2002), even though the two types of research methods constitute alternative strategies, it is advisable to view them as complementary to each other. Quantitative research methods provide breadth of the research whilst qualitative method provides the research with depth and detail.

6.4.1 Quantitative method

Quantitative methods are categorised as nomothetic methodology, where the main objective is to search measurable observations to understand things (Creswell, 1994; Collis and Hussey, 2014). This method follows a deductive approach to assess the validity of a theory, and combines the practices and norms of natural science which treats social reality as an external and an independent object (Bryman and Bell, 2011).

According to May (2001), findings generated from quantitative research can be generalised and the research may be replicated, due to its positivist inclination. However, the disadvantages of using quantitative method is that overreliance on the measurements, instruments and theory may jeopardise making the research to be distant apart from everyday reality (Bryman and Bell, 2011).

6.4.2 Qualitative method

Sarantakos (2013) defines qualitative research as a method of research that operates within a naturalistic and interpretive domain, guided by the standards and principles of a relativist orientation, and consists of a constructivist ontology and an interpretivist epistemology. With regards to the collection of data, the qualitative approach focuses more on words rather than numbers or quantification.

As qualitative method aligns with both constructionist/interpretivist paradigm and ideographic methodology, there is greater role for human nature in the ability to create the environment, rather than the environment influencing them; as they are assumed to have an urge to volunteer and are totally autonomous and free willed (Burrell and Morgan, 1979).

With regards to its data collection procedures, it may consist of interviews, documents and sometimes audio visual (Creswell, 2003). With qualitative method, the social world is understood or examined through interpretation of that world by participants (Bryman and Bell, 2011). It is often considered to be the most appropriate method in situations where limited or no meaning that can be deduced from numbers alone and is also seen as a method that is able to successfully bring together theory, human interaction, meanings and any relationships that may exist.

Critics of qualitative methods however, points out that the lack of replicability and results generalisation ability as the method's weakness (Bryman and Bell, 2011). Some critics also raised the issue on the method's active involvement of human actors as a weak point that make it lack objectivity (Morgan and Smircich, 1980).

6.5 Choosing a qualitative design

Due to this research having a small and specific focus in examining the drivers of green product innovation by marine equipment manufacturers within the EU, the qualitative method is adopted. This method is appropriate for this research as it requires a deeper understanding of the problem under investigation. This is in line with Denscombe (2007), who argued that knowledge generated through qualitative research is embedded in the conditions of social existence.

Furthermore, adopting a qualitative research strategy allows for more flexibility in research design and opening up possibilities for using and combining a range of data collection techniques, according to the social context in which the data were produced (Snape and Spencer, 2003). This include using interpretivism in this research to add further interpretation and meaning to the quantitative findings. The ambiguities and contradictions surrounding qualitative analysis were also considered.

Accordingly, the researcher is required to demonstrate personal awareness of questions about things, such as the inability of qualitative researchers to verify their truth statements (Denzin and Ryan, 2007). In addition, there is also the need to reflect on questions of interpretation (Denscombe, 2007) and criticisms about the limitation of findings to the research setting (Greenhalgh, 2006).

6.6 Data types

Data sources are generally categorised into two types: primary data and secondary data. As this research is done using primary data, the inappropriateness of employing secondary data in this research will be considered first.

6.6.1 Secondary data

Secondary data refers to data that is readily available but is published for other reasons other than the research problem at hand. Saunders *et al.* (2009) states secondary data could be gathered using different sources such as books, companies' annual reports, media sources and government publications. Researchers employing this method of data collection are aware of the main advantages that secondary data present: cost effectiveness, time saving, and sometimes the nature of the data even allows the researcher to conduct longitudinal analysis (Bryman and Bell, 2011).

However, employing secondary data also poses several limitations such as the lack of control over data quality, lack of familiarity with data, and sometimes the dataset might be incomplete (Saunders *et al.*, 2009). One key disadvantage of using secondary data is inherent in its nature, where the data was not collected to answer the researcher's specific research questions. In addition, the data may also have not been collected in the geographical region that is appropriate to the research, or that the variables may have been defined or categorised differently (Boslaugh, 2007).

Another key disadvantage is related to the process and the way the data has been gathered. The analyst of secondary data would not have known how well the data collection has been carried out. This raises concerns with regards to how serious the data may affected by problems such as low response rate, or respondent misunderstanding specific survey questions (Boslaugh, 2007). According to Boslaugh (2007), every data collection effort has its own deceitful ways that may not invalidate the data, but should be taken into account by the analyst.

Due to the abovementioned factors, the use of secondary data is therefore not appropriate for this research. Thus, the alternative method is to use primary data.

6.6.2 Primary data

Primary data involves the generation of new data set specifically for the research problem at hand. As such, primary data sources can be derived from respondents' analogous situations or experimentations (Kinnear and Taylor, 1996). According to Feinberg *et al.* (2012), in situations where a *"study require* *data about respondents' attitudes, perceptions, motivations, knowledge, and intended behaviour"* (p.66), it is crucial to ask people questions. Taking this into consideration, some of the techniques that are employed in this research includes interviews and questionnaires. The justification for using questionnaires and interviews as primary data sources for this research are examined in the next section. These two different methods of data collection were employed in this research for the purpose of triangulating the data collected (explained further in **Chapter 6.9**).

6.7 Questionnaire

Questionnaires are essentially a quantitative research method with roots in positivism and empiricism. The aim of using questionnaires in this research are: to standardise the test for strict comparability of findings; to reduce subjectivity through disengagement from the researcher; to use standardised statistical tests in analysis and to achieve validity and reliability through replicability and maximisation of impartiality. The quality of the questionnaire (its validity), is dependent on factors such as procedural integrity and transparency, sensitivity of interpretation, and credibility of results in the light of other research in the area.

There are numerous strengths and potential weaknesses of online surveys as highlighted by Evans and Mathur (2005) as discussed in the next section.

6.7.1 Major strengths

Global reach. According to the International Telecommunication Union, it was estimated that about 3.2 billion people (or almost half of the world's population) were using the Internet in 2015 (International Telecommunication Union [ITU], 2015). As such, Scholl *et al.* (2002) said that the basic drawback for the use of online survey research (the lack of representativeness) disappears due to the majority of society having access to the internet. This cause the Internet to become a valuable tool in obtaining information with ease and at a low cost from respondents living in different parts of a country or around the world.

Flexibility. The use of online questionnaire is also quite flexible as it can be conducted in several formats such as: email with embedded survey; email with a link to a survey URL or even a visit to a website by an Internet surfer who is then invited to participate in a survey. The format of the survey can also be in plain text or html (Schonlau *et al.*, 2002). In addition, the survey can be easily tailored to respondents' demographics or languages, by having more than one version of the questionnaire.

'Go to' capabilities. Online surveys can be designed in such a way that the respondents only answer questions that are specifically relevant to them. In other words, the survey can be tailored according to the respondents. This eliminates misunderstanding from respondent as complicated instructions (for example, *"If you answer Yes to Question 1, then continue with Question 3. If you answer No to Question 1, then go to Question 5"*) are not required. This involves utilising the software programme to manage skip patterns within a questionnaire, rather than having respondents manually skipping questions that are not applicable to them (Schonlau *et al.*, 2002). This reduces errors from respondents and makes the process of taking the survey simpler. This type of function is available on online survey platforms such as '*SurveyMonkey*', which provides its premium users with the option to skip respondents to a later page, or a specific question on a later page, based on their answer to a previous closed-ended question. This is done by applying the 'Question Skip Logic' function that is available on the platform.

Speed and timeliness. Online surveys can be carried out in a time-efficient manner which reduces the time taken to get a survey into the field and collecting the data. The speed and global reach of the Internet has also allowed data collectors with real-time access for interactions with geographically diverse respondent groups and information servers (Kannan *et al.*, 1998; Evans and Mathur, 2005). Furthermore, broadband access to the Internet also allows for the transmission of multimedia content, due to the speed of downloads, which enhances the scope and richness of online surveys. These factors have resulted to innovative internet-based methods such as online focus groups, chat rooms, and bulletin boards, where participants interact with each other along with the interviewer/facilitator in a multimedia setting.

Convenience. Online surveys enable respondents to answer at a time that is convenient for them. It also allows respondents to spend as much time as needed to answer each question. Some online survey platforms even allow respondents to start, and then resume back to the last question they left off at another time. As stated by Hogg (2003), respondents are no longer faced with being surveyed at an inconvenient time, such as with a telephone survey, as they can respond to the survey at a time that is convenient to them.

Ease of data entry and analysis. Online surveys conducted by companies will have much of the administrative burden of sending and receiving questionnaires and inputting data considerably reduced. After each respondent have completed their online questionnaire, the responses are automatically tabulated and analysed by the online survey software. As such, data collectors are not required to wait until the end of the survey period to see the results of the questionnaire. The data are also stored automatically in the database that can be retrieved anytime (Wilson and Laskey, 2003).

Question diversity. Online questionnaire also allows data collectors to include different question formats such as: dichotomous questions; multiple-choice questions; scales; questions in a multimedia format; both single-response and multiple-response questions and even open-ended questions.

Low administration cost. The cost associated with conducting a survey can be divided into two categories: preparation and administration. Preparation costs may be free with some online survey platforms offering their customers with basic packages. Costs are only incurred if data collectors require more functions that are not included in the basic packages, by paying for more premium packages. Administration costs are also low as results from the online questionnaires are automatically tabulated and analysed in a coordinated and integrated manner. Furthermore, as online surveys are self-administrated, costs are kept further down as postage nor interviewers to carry out the survey are not required.

Ease of follow-up. As sending out email does not cost anything, data collectors are able to send out follow-up reminders to respondents with ease. Online survey software such as '*SurveyMonkey*' allows it users to identify each respondent that has yet to complete the survey. This is made possible as each recipient receives a unique survey link that ties their survey to their email address. This allows users to track their responses and to send a follow-up email to those respondents who have yet to respond.

Eliminates interaction with respondents. Online surveys eliminate the need for interviewer to interact with respondents. As such, interviewer biasness and other possible interviewer errors are avoided since the surveys are controlled and self-administered (Evans and Mathur, 2005). Furthermore, online surveys are a less intrusive way of gathering information on sensitive topics, compared to personal or telephone surveys.

Large sample is easy to obtain. The simplicity with which messages can be constructed and emailed to respondents, along with the access to global databases, allows online surveys to gather large sample size with ease (Evans and Mathur, 2005). If the survey is to be disseminated globally, data collectors need to use sampling and programming methods that consider the variation in each unique culture and languages. This is so that the results gathered is well-founded.

Required completion of answers. Online surveys can be designed in such a way that respondents must answer a question before they are able to move on to the next question, or even allowed to complete the survey. This eliminates unanswered questions that may affect the overall findings of the survey. Furthermore, the survey can also be designed to ensure respondents only select one answer to a question; unless the question specifically states otherwise. This eliminates the possibility of respondents answering the question incorrectly.

6.7.2 Major potential weakness

Perception as junk mail. Unsolicited junk mail, or ‘spam’, is a big problem for online surveys. This is due to the difficulties faced by respondents in distinguishing between a legitimate survey and a spam message. Respondents’ email server may also filter such emails into their ‘junk’ folder. Even if the email came from a trusted source and managed to get through to respondents’ ‘inbox’ folder, there is still the likelihood that respondents will not click on the survey link that will direct them to an external website.

Unclear answering instructions. Online surveys are self-administrated and with that, it comes with its own set of challenges. Instructions for answering the questionnaire needs to be extremely clear. Ambiguous instructions only confuse respondents and can potentially cause them to exit the survey without completing the entire questionnaire.

Impersonal. Due to the impersonal nature of an online survey and the lack of human interaction, respondents may not be motivated to participate. Data collectors may then need to provide motivational aids to encourage respondents to participate. This include giving respondents a chance to win gift vouchers or cash prizes upon completion of the survey.

Based on the discussions above, it is evident that the advantages of using questionnaire as a primary data source for this research, outweighs the disadvantages. Furthermore, the disadvantages associated with using questionnaire can be easily avoided by taking appropriate measures and steps to ensure that it does not pose as a problem. This include using clear and concise language and instructions in the questionnaire for ease of understanding by respondents. Thus, the issue with incomplete questionnaires due to unclear answering instructions, is eliminated.

The next section examines and justify the use of interview as another primary data source for this research.

6.8 Interviews

According to Ghauri and Gronhaug (2010), a limited number of interviews or observations are usually employed by researchers in qualitative research to explain the studied concept. Interviews have been widely used as an effective research instrument for eliciting knowledge and perceptions (Hyman, 1975; Briggs, 1986; Arksey and Knight, 1999; Gray, 2014).

The process of interviewing provides the researcher with the opportunity to be an integral part of the whole interview process, from designing the questions through to the analysis of the data. An interview is a two-way informational street where meaning is constructed interactively and often involve collaborative meaning-making (Holstein and Gubrium, 2004; Doucet and Mauthner, 2008).

The advantage of collecting data through interviews is that it provides the researcher, or interviewer, the flexibility to clarify the meaning of the questions with participants. It also allows room for the interviewer to explain and further expand on the questions, follow-up on the questions and prompt participants when they have reached an important topic (Bryman, 2001; Leeuw, 2008).

Face-to-face interviews also provides the interviewer with the opportunity to actively structure the interview situation and observe non-verbal communication. This is useful in situations when it is hard to decipher what respondents are saying, or when they use hand gestures to communicate or describe something. Interviewers are also able to address any sensitive issues, practices or experiences related to the interview questions comfortably (Lee, 1993; Snape and Spencer, 2003).

However, the disadvantages of an interview can arise from the presence and intrusion of the interviewer (Rubin and Rubin, 1995; Denscombe, 2007). It can also be time-consuming as the entire process include setting-up the questions, conducting the interview, transcribing and analysing the data. There may also be issues during transcribing, where the interviewer may need to repeat interviewees' points or describe what they had explained to capture the correct information.

6.8.1 Semi-structured interviews

According to Sarantakos (2013), there are various types of interviews, each producing different kinds of results: Delphi, ethnographic, biographical, open, panel interviews, structured and *et cetera*.

For this research, semi-structured interview was employed due to the flexibility it offers. It lies somewhere between the structured and unstructured types (Sarantakos, 2013). In other words, although semi-structured interview is structured by means of a topic guide (schedule), it provides the interviewer with the flexibility to be open to each informant's way of discussing the topics and other topics relevant to the discussion. As such, the interview can be conveniently tailored to suit the social encounter, without necessarily over-restricting interviewees or giving them too much leeway.

However, the interviewer still needs to be reflective during the research process (Hammersley and Atkinson, 1995; Fielding and Thomas, 2008). This is where the interviewer needs to knowingly and meticulously attend the interviewee process by keeping *"track of what is being asked about in the interview, and in turn, what is being conveyed by respondents"* (Holstein and Gubrium, 2004, p.69). As the interview is semi-structured, the schedule may be used as an 'aide memoire'. This makes it easier for the interviewer to keep track of the interview process by treating the topic guide as a checklist, by crossing out the points either mentally or physically once it has been covered; rather than following it religiously.

It may also prove to be challenging for the interviewer, from having to occasionally glance at the checklist and cross out topics that has been covered as the interviewee is making their responses. Furthermore, the interviewer may also have to juggle with linking up to what the interviewee has mentioned to the points that have yet to be covered, in a bid to make it easier for the conversation to flow. As such, it is important that adequate preparations are done to avoid having the interview process moving from ‘order’ to ‘chaos’ (Blaxter *et al.*, 1996).

6.8.2 Qualitative analysis

There are two main analysis method used in qualitative research: thematic content analysis; and, narrative analysis. Another approach is the use of a computer software to analyse data.

<u>Thematic content analysis</u>

This is the most common method used in qualitative research, which aims to find common patterns across a data set. This usually involves the following steps:

- Data familiarisation (reading and re-reading data).
- Coding (labelling) the whole data set.
- Looking for themes with broader patterns of meaning.
- Reviewing themes to ensure it fits with the data.
- Defining and naming themes.
- Writing up (creating a coherent narrative that includes quotes from the interviewees).

<u>Narrative analysis</u>

This approach is mostly used in social sciences where it aims to make sense of stories, and involves the following steps:

- Gather the stories.
- Analyse each story and look for insights and meanings.
- Compare and contrast different stories; look for interpretations.

- Writing up (creating a new story that connects the previous ones in an insightful way)

NVivo

Analysing qualitative data is be a time-consuming process due to the large amount of information collected. As such, researchers felt the need for information technology (IT) support to help them with some of the cumbersome processes involved. The first software to assist researchers with their analysis was launched in the 1980s and has since continued to develop, with *NVivo 10* that was launched in 2012 (Davies and Hughes, 2014).

According to Davies and Hughes (2014), researchers that have used this software claims that it has transformed the time-consuming and complex tasks of analysing qualitative databases ‘by hand’. Among other things, *NVivo* helps the researcher to store data conveniently, maintain a research record and enables researchers to import and export information into different software packages such as Word, PowerPoint and Excel. *NVivo* is basically a powerful software that allows researchers to handle large datasets, perform complex searchers at the click of a button, and organise materials that might otherwise be overlooked.

Like all other computer programs, *NVivo* is a tool which requires its users to have developed the necessary skills to use it effectively. It is also important to realise that the software does not have a ‘human touch’, so researchers are still required to do the thinking process. This varies from open coding to inductive theory building which requires a person to bring creativity and originality to the data. Although *NVivo* is unable to identify themes in the data, the software can search for reoccurrences once the theme has been identified and classified by the researcher. In that respect, *NVivo* is a handy tool that can save researchers a lot of time from having to sift through data.

In this research, data from the semi-structured interviews were analysed using thematic content analysis, with the help of *NVivo* to organise, retrieve and present the data in an effective and more coherent way.

6.9 Triangulation

According to Denzin (1989), triangulation refers to the combination of methodologies in the same study. It enables the researcher to tackle different angles of the problem at hand and increases the likelihood of the research to achieve a high level of validity and credibility whilst overcoming single method limitations (Bryman and Bell, 2011).

Essentially, the assumption in triangulation is that its effectiveness lies on the premise that the weakness in each single method would be compensated by the counter-balancing strengths of another (Amaratunga *et al.*, 2002). There are many different types of triangulation such as data triangulation, observer triangulation, methodological triangulation and theory triangulation (Robson, 2011). As this research aims to cross-validate the data from two different sources of data collection methods, data triangulation was employed in this research.

Data triangulation refers to examining the consistency of different data sources from within the same method such as making a comparison among people with different viewpoints (Denzin, 1989; Robson, 2011). The use of qualitative and quantitative method to study the same topic is therefore, a useful tool for gaining insights and results. It can also be used to assist researchers in making inferences and in drawing conclusions, as shown in **Figure 6-3**.

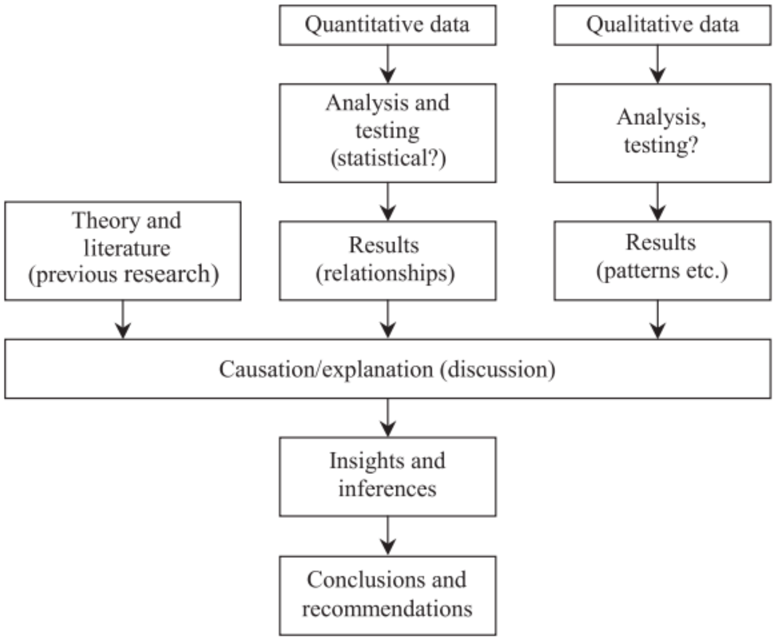


Figure 6-3 Data triangulation

Source: Amaratunga *et al.* 2002 p.24

This type of triangulation is used to not only cross-validate the data but also to capture different dimensions of the same phenomenon. In this research, data triangulation is used in the case of the marine equipment manufacturers to determine the variables that encourage or restrict innovation in green ship technology by using two data collection techniques: questionnaire and semi-structured interviews.

The benefit of using two different methods to collect data allows the researcher to obtain different information that could complement one data set with another. Nonetheless, critics of triangulation point to the fact that it is difficult to replicate results since personal perceptions are involved (Jick, 1979).

6.10 Methodological design

Development of the questionnaire and semi-structured interview questions were done based on the literature review, and with the research methodology in mind.

The questionnaires were designed carefully to ensure that the answers given by respondents produce the required information. In addition, ambiguous questions were also avoided as it does not yield useful data. It can also cause frustrations to respondents, which may then discourage them from completing the questionnaires. A pilot test of the questionnaire was carried out with a group of acquaintances who are working in the shipping industry.

Data from the pilot test were then analysed to check that the analysis method can offer the results this research aimed for. Analysis of the data was done automatically by the online survey software, *SurveyMonkey*, where the results were tabulated and analysed after each completion of the questionnaire. If results from the pilot test is unsatisfactory, feedback from the test participants are gathered to further improve on the outcome of the questionnaire. This could include restructuring the questionnaire or creating new questions.

There are two sets of questionnaires – one for the ship-owners and one for the marine equipment sector. The respondents for the questionnaire are from the senior managerial positions of companies for both the ship-owning companies and the marine equipment sector, that specialises in innovating new products to meet the stringent regulations currently faced in the shipping industry.

The set of questionnaires for the ship-owners are aimed at identifying the solution that has been or will be implemented on vessels to meet the global low sulphur regulation of 0.5 percent by 2020. This questionnaire will highlight the processes involved and the ship-owners' reasoning behind the chosen solution implemented on their fleet.

The set of questionnaires for the marine equipment manufacturers on the other hand, is aimed at identifying the variables that encourages or restricts green product innovation; specifically, in relation to meeting the low global sulphur regulation of 2020. The responses will highlight if institutional climate of both the EU and the IMO have an impact on the level of innovation in green ship technology.

As for the interview questions, there are four points which need to be adhered to: (1) use open-ended questions, (2) avoid leading questions, (3) probe issues in depth, and (4) allowing the informant to lead. The interview questions are generated from the responses analysed from both sets of questionnaires that were disseminated to the ship-owners and marine equipment manufacturers in order to have a deeper and stronger understanding of the subject being researched (Denscombe, 2010). The participants for the semi-structured interviews however, will only consists of individuals from the marine equipment sector. This is due to the focus of this research that is aimed at investigating the drivers of green ship technology in the marine equipment industry. This therefore makes it crucial to narrow down the participants for the semi-structured interview to the targeted group to have more direct and specific responses.

The data from the ship-owner's questionnaire however, will have an influence on how the questions for the semi-structured interviews are constructed. This is because the data will highlight whether any equipment or specific technology were implemented on ship-owners' fleet to meet the stricter regulations, along with the processes and reasoning involved for the selection. This data was then used to tailor to the equipment manufacturer's questionnaire, where the questions revolved around investigating whether ship-owner is one of the variables that either encourage or restrict innovation in the marine equipment sector.

Data from the interviews will be consolidated and analysed. There are two ways in which the data can be analysed: thematic and narrative. According to Braun and Clarke (2006), thematic analysis is a way of seeing, as well as a process for coding qualitative information. This process involves many decisions made from the analyst, regarding the process of identifying themes and explaining why specific categories were chosen. Decisions must also be made whether to analyse the interview data obtained from each participant independently or whether to use cross-case analysis.

On the other hand, narrative analysis is a form of qualitative analysis where the analyst focuses on how respondents to the interview impose order on the flow of experience in their lives and thus make sense of events and actions in which they have participated (Schutt, 2012). Narrative analysis also consists of coding and in this case, revolves around reading the responses and classifying them into general patterns. The type of analysis used will be decided after the interviewing process.

6.11 Evaluation of research

Qualitative research is often based on subjective, interpretive and contextual data. This makes the findings more likely to be scrutinised and questioned. As such, it is crucial for researchers doing qualitative research to take necessary steps and precautions to ensure the validity and reliability of their research findings. The findings need to be believable, consistent, applicable and credible if other researchers are to benefit from it.

Validity

According to Oliver (2010), validity is a compulsory requirement in all research. It is concerned with whether the research is believable and true, and whether it is evaluating what it is supposed or purports to evaluate. In other words, it is the precision in which the findings accurately reflect the data. This makes *validity* a crucial criterion for evaluating the quality and acceptability of research (Burns, 1999).

There are different forms of research validity but according to Cohen *et al.* (2011), the main ones are namely: content validity, criterion-related validity, construct validity, internal validity, external validity, concurrent validity and face validity. Researchers could ensure the validity of their research by, but not limited to:

- Choosing appropriate methodology after taking into consideration the characteristics of the research; and
- Not placing any pressure on respondents when they are giving their responses.

Selecting appropriate sample method for the research is also important. Researchers generally use different instruments when gathering data. The quality of these instruments is therefore very critical as *"the conclusions researchers draw are based on the information they obtain using these instruments"* (Fraenkel and Wallen, 2003, p.158). This then makes it important for both the data and the instruments to be validated.

Reliability

One of the main requirements of any research process is the reliability of the data and findings. According to Blumberg *et al.* (2008), reliability is the extent to which the same results could be obtained using the same instruments more than once. In other words, if a research is associated with high levels of reliability, other researchers should be able to generate consistent results which does not varies, under similar circumstances. Reliability therefore deals with the consistency, dependability and replicability of *“the results obtained from a piece of research”* (Nunan, 1992, p.14).

It is rather straightforward when it comes to obtaining similar results in quantitative research as the data are in numerical form. However, it is rather demanding and difficult when it comes to obtaining identical results in qualitative approaches as the data are in narrative form and is subjective. In this respect, Lincoln and Guba (1985) suggested that instead of obtaining the same results, it is better to think about the dependability and consistency of the data. The purpose of the researcher therefore, is not in obtaining the same results but rather, to agree that the findings and results are consistent and dependable based on the data collection processes.

According to Lincoln and Guba (1985) and Merriam (1998), dependability of the results could be ensured through the use of three techniques: the investigator’s position, triangulation and audit trail. For the first technique, the researcher could increase the reliability of the research by explicitly explaining the different processes and phases of the inquiry. As such, the researcher should elaborate on every aspect of the research and describe in detail on the rationale of the research, its design, and the subjects. As for the second technique, the researcher should employ different procedures when collecting data such as by using questionnaires and interviews.

In addition, this information would also need to be gathered through different sources such as ship-owners, equipment providers, regulators. As such, collecting varied types of information through different sources could increase the reliability of the data and the results. This then makes replication of the research to be executed easily. Finally, with regards to audit trail, the researcher should describe in detail how the data are collected and analysed, how different themes emerged, and how results are obtained. This detailed information could then help other researchers to replicate the work and contribute to its reliability.

Reliability issues could also arise in a research which uses a single observer as the source of data. Babbie (2010) sees this as a concern as the research would have no certain guard against the impact of the observer's subjectivity. According to Wilson (2010), reliability issues are usually closely associated with subjectivity. The level of reliability of the research would be compromised once the researcher adopts a subjective approach towards the work.

It is important to realise that although the risks to research validity and reliability can never be completely avoided, researchers need to attempt to minimise such risks to the best of their ability (see **Chapter 9** for validity and reliability of this research).

6.12 Research ethics

Research integrity is important in all research. Integrity in research could be categorised into two broad areas: the pursuit to produce knowledge, and in working with others (O'Leary, 2010). The researcher's responsibility in the pursuit to produce knowledge is in ensuring that the 'truth' has been captured. This means that the researcher should have reached a conclusion that were not tainted by error and unrecognised bias; and that the research has been conducted with professional integrity. With regards to working with other people, it is the researcher's responsibility, being an ethical one, in ensuring that the rights and well-being of those involved in the research are always protected.

As the objective of conducting a research is to produce new knowledge, knowledge that others would come to trust and rely on, the production of this knowledge would need to be credible. According to O'Leary (2010), this knowledge therefore *"must have the power to elicit belief"* (p.29). This could be demonstrated by a range of indicators such as reliability, validity, authenticity, neutrality, and audibility (O'Leary, 2010). Based on these indicators, it would show that the research has been approached as disciplined rigorous enquiry. As such, the knowledge produced are more than likely to be accepted as a valued contribution to knowledge.

According to O'Leary (2010), ethics are the principles or rules of behaviour that act to dictate what is actually acceptable or allowed within a profession. The ethical guidelines for the conduct of research however, are different across professional code, discipline area and institution. Research ethics for this study has been achieved in the following areas:

<u>Ensuring sufficient informed consent has been given by respondents</u>

'Informed consent' could only be given by participants after they have had a full understanding of their requested involvement. This involve notifying participants of the time commitment, type of activity, and topics to be covered. Informed consent implies that participants are:

- Competent: participants have realistic intellectual capacity and psychological maturity;
- Autonomous: participants can make self-directed and self-determined choices;
- Involved voluntarily: participants were not forced, pressured, or duped into participating; and,
- Aware of the right to discontinue: participants were under no obligation or pressure to continue their involvement in the research.

Ensuring confidentiality and, if appropriate, anonymity

Confidentiality involves protecting the identity of all participants that are involved in this research; all identifying data remains solely with the researcher. Due diligence has been taken to ensure participants' identity could not be ascertain from the information provided in this research. Otherwise, prior approval for disclosure was seek from the respondent. Anonymity on the other hand, goes a step beyond confidentiality. It refers to protection against identification, even from the researcher. In other words, information, data and responses collected anonymously should not be identifiable with any respondent.

Other than masking participants' identity, protection of confidentiality and anonymity in this research was also achieved through: restricted access to data; secure storage of raw data; permission required for subsequent use of data; and, eventual destruction of raw data.

6.13 Summary

To summarise, this research follows the social constructionism research paradigm and is inductive in nature. The research employs a qualitative strategy and uses data triangulation for the collection of data. Data triangulation was employed as it allows the cross-checking of findings from one method of data collection with another very different method (Denscombe, 2010). Semi-structured interviews is the main method used and questionnaire (quantitative) is used in conjunction with the interviews to gather statistical data about responses and also to contextualise and extend the analysis being carried out (Blaxter *et al.*, 1996). This results in a deeper and stronger understanding of the subject being researched (Denscombe, 2010).

CHAPTER 7 STAGE 1 DATA COLLECTION – QUESTIONNAIRES

7.1 Introduction

As covered in **Chapter 6**, the fieldwork for this research employs a qualitative strategy and uses data triangulation for the collection of data. Questionnaires were used in the first phase of the data collection process, where two different sets of questionnaires were sent out to two different target groups: ship-owners and marine equipment manufacturers. This chapter include: design of the questionnaires; questions justification; testing of the questionnaires; sampling for the questionnaires and administration of the questionnaires. Results from both sets of questionnaires are then presented and analysed, before the chapter concludes with a summary.

7.2 Research questionnaires

The aim of the first stage of the data collection is to gather responses from ship-owners and marine equipment manufacturers on matters related to the global 2020 low sulphur regulation.

The set of questionnaires for ship-owners seek to investigate the solutions or measures ship-owners has implemented or will be implementing on ships to meet the regulation. This involves investigating a range of factors that impacts ship-owners' decision-making process when selecting an appropriate measure to comply with the regulation.

Results from this questionnaire highlights the level of preparedness of the shipping industry to meet the 2020 low sulphur regulation. But more importantly, the results highlight whether ship-owners' demand for a product to meet the regulation, directly encourages green product innovation within marine equipment manufacturers.

The questionnaire for ship-owners is divided into the following sections, covering:

- Sulphur emission control areas (SECA);
- EU Directive 1999/32/EC;
- Potential future ECA;
- Global 0.5 percent sulphur limit implementation date;
- MARPOL Regulation 14.8 (fuel availability study);
- Sulphur cap deadline of 1 January 2020;
- Retrofitting scrubbers; and,
- Solution(s) to meet 2020 regulations*.

*(*completed <u>only</u> by respondents who has chosen a solution to meet the sulphur regulation).*

On the other hand, the set of questionnaires for the marine equipment manufacturers seek to investigate the variables that affects or promotes the level of green product innovation within the sector. This product innovation is specifically related to products that ship-owners can implement to meet the stricter global sulphur regulation.

Results from this questionnaire highlights the factors encouraging manufacturing companies to innovate and the barriers they faced.

The questionnaire was divided into the following sections, covering:

- Products offered to meet the sulphur regulation;
- Reasons for entering the market;
- Approval/certification process; and,
- Factors affecting product innovation.

For both sets of questionnaires, the categories were decided and identified in accordance to the theme of this research and based on the literature review. Within each category, specific questions were formulated in direct reference to the research questions and key focus of this research. This helps to achieve the overall aim of this study.

7.2.1 Question design

Both sets of online questionnaires were designed for self-completion. With that in mind, the wording and formatting of the questions needed to be clear, straightforward in language and in a format that was easy to follow throughout the course of the questionnaire. Furthermore, it was crucial to also explain and clearly state the way respondents should answer the questions. This was to avoid inadmissible answers by respondents, as it would impact on the overall results of the questionnaires.

One consideration that was taken when designing the question format was to include as many answers as possible in the form of ordinal scales rather than interval scales despite its desirability of not only knowing the order, but also the exact differences between the values. This was due to the fact that many dependent variables possess an ordinal scale of measurement, where the differences among values composing the scale were unequal in terms of what was being measured, permitting only a rank ordering of scores (Harwell and Gatti, 2001).

Therefore, since ordinal scales are typically a measurement of non-numeric concepts like satisfaction, happiness, discomfort and so on, only the order of the values is important and significant in the questionnaire. As such, particular use was made of the Likert-type scale (Gliem and Gliem, 2003).

Questions designed in this manner are typically composed of approximately an equal number of favourable and unfavourable statements concerning the attitude object. Respondents were asked to answer to each statement based on their degree of agreement or disagreement with the statement. The respondents were instructed to select one out of five responses: strongly agree, agree, undecided, disagree, or strongly disagree. However, a slight variation on this was used in for example, Question 19 of the ship-owner's questionnaire, where respondents was asked to indicate how worried they were about price fluctuations of low sulphur fuel.

Some of the answer scales from both sets of questionnaires were unipolar such as that in Question 19, which ranged from 'not worried' to 'worried', while others were bipolar, for example the attitudes in Question 28 of the ship-owner's questionnaire, which ranged from 'unconcerned' to 'concerned' with a neutral middle point 'neither unconcerned nor concerned'. For both types, a five-point scale was used as it was deemed a sufficient degree of gradation.

These levels of measurements are essentially ordinal measures, but the data is typically treated as interval/ratio, which assumes the intervals between the given groupings are conceptually equal (Nardi, 2003). Taking the example in Question 19 of the ship-owner's questionnaire, the difference between 'not quite worried' and 'somewhat worried' is the same 'distance' as the difference between 'somewhat worried' and 'quite worried'.

To further reduce the degree to which this assumption could be questionable, the answer scales were offered as numbers in brackets, at the end of the worded groupings. This consequently made the answer scales to appear more as continuous scales than ordinal groupings. In some questions however, scalar answer was not appropriate for use. These questions were therefore offered categories instead, which applies mainly to those where a 'yes' or 'no' response was needed. Categories were also be used in certain questions where it would be used as explanatory variables in analyses.

In order to avoid constantly prompting respondents of possible answers by offering categories, some open-ended questions were also included in the questionnaire. The advantage of this method was that respondents had the opportunity to indicate their own responses without fitting it to given categories. Furthermore, it allowed the researcher to gain deeper insights into respondents' views on the subject being asked (Soukka, 2012). The answers given were then coded post hoc into nominal categories which were drawn up from the range of responses given. In cases where responses in more than one category were given in the questions, more than one response was recorded.

Inevitably, the overall questionnaire length was a limiting factor in its design. Some questions had to be discarded, in order to keep the length of the questionnaire feasible. The result of this was that some constructs had to be measured by one question only, where several questions would have provided a better measure. The final version of the questionnaires however, was the result of a judgement regarding trade-offs between quality and covering all areas of interests, and the likely response rates given the length.

7.2.2 Questions justification – Ship-owner questionnaire

Question 1:

Please indicate your position within the company

Answer choices:

Senior management / Mid management / Junior management / Technical staff / Other (please specify)

At the start of the questionnaire, respondents were asked to state their position within their respective companies. This ranged from junior management to senior management level, technical staff and ‘other’ positions, where respondents need to specify.

Getting to know each respondent’s position within their company is important in this questionnaire, as it informs the data collector on the validity and reliability of the information given. The higher the respondent’s position is within the company, the more likely the information given is a true reflection of the overall view and direction of the company. However, it is important to highlight that some of the responses may be the personal views of the respondent, which may or may not correspond with the overall views of their company.

The first section of the questionnaire covered matters related to the sulphur emission control areas (SECAs). Ships trading within these areas need to comply with the 0.1 percent sulphur limits that were enforced on 1 January 2015 (IMO, 2014c). This section therefore, aims to identify the solutions that have already been put in place by ship-owners to meet the regulation. This highlights whether fuel alternatives or technological products were the preferred solution implemented by ship-owners when trading within SECAs.

Question 2:

Are any of your company’s fleet trading in the designated SECAs of the Baltic Sea or the North Sea?

Answer choices:

Yes / No

In this section, respondents were first asked if any of their fleet were trading in the designated SECAs of the Baltic Sea or the North Sea. The purpose of this question is to identify respondents who trades within SECAs and those that does not, in order to direct each respondent to the next relevant question.

Respondents who answers ‘No’, as none of their ship trades within those areas, were directed to the next section of the questionnaire on EU Directive 1999/32/EC (Question 7). Respondents who answers ‘Yes’ were directed to the next question in this section (Question 3).

Question 3: In the course of a month, how often does your company’s fleet trade in these areas? **Answer choices:** 1-15 times / 15-30 times / Mainly trade within SECA

Respondents were then asked on the frequency at which their fleet trades in the designated SECAs of the Baltic Sea or the North Sea in the course of a month.

Identifying the frequency at which respondent’s fleet trades within those areas may imply the rationale behind implementing the chosen measure (in Question 4) to meet the regulation. In other words, the solution implemented by ship-owners may be dependent on the number of times the ship trades within SECAs.

Question 4: How does your company comply with the regulation of having less than 0.1 percent sulphur content in fuel when trading in these areas? (Please tick all that apply). **Answer choices:** Low sulphur fuel oil / Using gas as a fuel / Scrubbers / Methanol / Battery power / Biofuels / Other (please specify)

Respondents were then asked to select all the measures, based on the list provided, that were implemented on their fleet to comply with the 0.1 percent regulation. The measures provided in the list include using alternative fuels such as low sulphur fuel oils and methanol and implementing technological solutions such as retrofitting scrubber systems onboard. These measures were based on those measures identified from the literature review (see **Chapter 4**). The 'other' option was also provided to respondents for them to indicate the measures they have implemented that were not in the list. This highlights the measures that are currently in place on ships to meet the 0.1 percent sulphur limits.

Question 5:

Based on your answer for Question 4, will your company be employing the same solution to comply with the global 0.5 percent sulphur cap coming into effect on 1 January 2020?

Answer choices:

Yes / No

Although the sulphur content of 0.1 percent in SECAs are lower than the global sulphur limits of 0.5 percent, the measures identified can still be used by ship-owners to meet the global sulphur regulation. As such, respondents were then asked if they would employ the same solution used to comply with the 0.1 percent sulphur limit, to comply with the 0.5 percent low sulphur regulation coming into force on 1 January 2020.

The answer to this question may suggest that there are certain advantages and disadvantages associated to each adopted solution, to result in respondents either wanting to employ the same solution for the 2020 regulation, or not. Respondents who answers 'No' were directed to the next question in this section

(Question 6), while respondents who answers ‘Yes’ were directed to the next section of the questionnaire (Question 7) on EU Directive 1999/32/EC.

Question 6:
Please briefly explain why your company will not be employing the same solution?
Answer choices:
(Open-ended question)

Respondents were asked to explain the reason(s) for not wanting to implement the same solution for the 2020 global low sulphur regulation. As respondents would have identified the advantages and disadvantages associated to their implemented solution based on experiences, they were able to justify the reason(s) why they chose not to employ the same solution. This information is crucial and is of benefit to other ship-owners that have yet to decide on a solution to comply with the 2020 regulation.

However, it is important to consider that the reason(s) provided may not be applicable to all users of that solution, as it varies differently among companies depending on the nature and scale of their business. In other words, the disadvantages associated to a solution highlighted by one respondent, may be considered as an advantage to another respondent.

The next section of the questionnaire covered EU Directive 1999/32/EC, with regards to the reduction of sulphur content in liquid fuels for ships trading within the EU (EC, 2016b). This directive is like IMO’s MARPOL Annex VI regulations but include requirements that were introduced by the European Commission that went beyond IMO rules. The additional requirements, under EU Directive 2005/33/EC, were introduced in recognition of the need to further improve air quality for the protection of human health beyond SECAs. One such requirement is the need for ships at berth or anchorage in EU ports, to use fuel with a maximum sulphur content of 0.1 percent (EC, 2016b).

This section is included in the questionnaire as the sulphur limits under the regulation is like the limits within the sulphur emission control areas. As such, this section also aims to identify the solutions that have already been put in place by ship-owners to meet the stricter sulphur regulation. This highlights whether fuel alternatives or technological products were the preferred solution implemented by ship-owners when trading within the EU.

The purpose of this section is also to maximise the number of respondents who have implemented a solution to comply with the 0.1 percent sulphur regulation. This is crucial as respondents who have implemented a solution for the regulation, may have been excluded from participating in the previous section, as they do not have ships trading within SECAs. As such, this section aims to include those respondents in order to maximise the findings to this phenomenon and in strengthening the results.

Question 7:

Is your company affected by the above-mentioned requirements?

Answer choices:

Yes / No

Respondents were first asked if they were affected by EU regulation of having less than 0.1 percent sulphur content in fuel whilst at berth or anchorage within the EU. The purpose of this question is to identify respondents affected and unaffected by this regulation, in order to direct each respondent to the next relevant question.

Respondents who answered ‘No’, as they were not affected by the EU regulation, were directed to the next section of the questionnaire on potential future ECA (Question 12). Respondents who answered ‘Yes’ were directed to the next question in this section (Question 8).

Question 8: How often does your company’s fleet use EU ports in the course of a month? **Answer choices:** 1-5 times / 15-30 times / Mainly uses EU ports

Like the previous section of the questionnaire (on sulphur emission control areas), this section also seeks to:

(i) identify the number of times respondent’s fleet uses EU ports within the course of a month;

Question 9: For those vessels in your fleet that use EU ports, how does your company comply with the regulation of having less than 0.1 percent sulphur content in fuel? (Please tick all that apply). **Answer choices:** Low sulphur fuel oil / Using gas as a fuel / Scrubbers / Methanol / Battery power / Biofuels / Other (please specify)

(ii) identify the solutions implemented by ship-owners to comply with the regulation;

Question 10:

Based on your answer for Question 9, will your company be employing the same solution to comply with the global 0.5 percent sulphur cap coming into effect on 1 January 2020?

Answer choices:

Yes / No

(iii) investigate if respondents were employing the same solution used to comply with EU regulation, to comply with the global 0.5 percent sulphur cap; and lastly,

Question 11:

Please briefly explain why your company will not be employing the same solution?

Answer choices:

(Open-ended question)

(iv) identify the reason(s) why the same solution is not employed.

The questionnaire then moves on to the next section, covering the potential spread of emission control areas (ECAs). As covered in **Chapter 3.4.1.3**, there were reports suggesting that the emission control areas were more than likely to include new areas in the near future. The areas under consideration include Australia, Japan, the Mediterranean and Norway (Rickmers-Linie, 2014).

It is important to investigate the potential spread of ECA as it may affect ship-owners decision-making process, in selecting the best solution for their fleet to comply with the stricter sulphur regulation. This is brought about by the uncertainty in the price difference of 0.1 percent sulphur fuel and 0.5 percent sulphur fuel, as covered in **Chapter 4.3.1**. In the scenario where the price differential between the two types of fuel is significant, and the ship is sailing more frequently in ECAs, the overall operating costs of the ship is affected. Ship-owners may then consider adopting technological products to comply with the regulation.

This is the reason behind the importance of investigating in the potential spread of ECAs, as it may have an impact on ship-owner's decision to either use alternative fuels or adopt technological products to comply with the global sulphur regulation.

Question 12:
Will your company be affected by the spread of ECAs?
Answer choices:
Yes (please briefly explain why) / No

In this section, respondents were first asked if their company would be affected by the spread of ECAs. The response to this question indicates the number of ship-owners that may need to re-consider their solution to meet both the global sulphur regulation and the potential 0.1 percent regulation enforced in those areas.

Respondents who answered 'Yes' were asked to briefly explain the reason. The reason(s) provided may indicate the concerns and worries faced by ship-owners should the potential ECAs be implemented. Respondents who answered 'No' were directed to the next section of this questionnaire (Question 14).

Question 13: Does this impact your company's decision regarding a solution to comply with the global 0.5 percent sulphur cap? **Answer choices:** Yes (Please briefly explain what your company's long-term solution is?) / No

Respondents who were affected by the potential spread of ECAs were then asked to indicate whether it impacted their decision on the solution to comply with the 2020 regulation. Respondents who answered 'Yes' were then asked to explain what their long-term solution would be.

Responses to this question highlights the potential solution that ship-owners would implement to comply with both 0.1 percent and 0.5 percent sulphur regulations.

The questionnaire then moves on to the next section, on issues surrounding the implementation date of the global 0.5 percent sulphur regulation. The aim of this section is to investigate whether the shipping industry were satisfied with IMO's decision to implement the regulation on 1 January 2020, instead of delaying it by five years to 1 January 2025 (IMO, 2015b).

Question 14: Do you think the IMO have made sufficient efforts to consult with industry players before agreeing to reduce global SOx emissions to 0.5 percent from 2020? **Answer choices:** Yes / No (Please briefly explain what more the IMO could have done to consult with industry players?)

The section starts by asking respondents if they felt sufficient efforts has been made by the IMO to consult industry players, before agreeing to reduce the global SOx emissions to come into force in 2020. This is to investigate whether ship-owners would have had the opportunity to have an influence on the outcome of the implementation date of the regulation. This is due to the regulation having a direct impact on their operations and therefore, may have preferred to have been consulted in the process. This could have resulted in ship-owners being given more time to consider available solutions to meet the regulation.

As respondents who answered 'No' may feel that the IMO had not made sufficient efforts to consult with industry players, they were asked to explain what more the IMO could have done. This information may have an influence on why some ship-owners may not be able to meet the low sulphur requirements by the enforcement date.

Question 15:

Can you provide an example of how the IMO has reached out to industry players?

Answer choices:

(Open-ended question)

Respondents who answered 'Yes' to IMO having made sufficient efforts to consult with industry players, were asked to provide with examples. This highlights the measures undertaken by the IMO to consult with industry players.

Respondents were then directed to the next section of the questionnaire on MARPOL Regulation 14.8, which is related to the fuel availability study that was commissioned by the IMO. The study was completed ahead of the 2018 deadline in July 2016 (CE Delft, 2016). The aim of this section is to investigate issues surrounding the predicted availability of compliance fuel, as the outcome of the review saw the IMO sticking with the 1 January 2020 implementation date, instead of delaying it to 1 January 2025.

As ship-owners were not consulted in the study, it is important to investigate their thoughts on the matter as issues surrounding the availability of compliance fuel affects them directly. The predicted amount of compliance fuel available may also affect their decision-making process when deciding on a solution to comply with the sulphur regulation.

Question 16:

Do you think ship-owners should also have been consulted in the review?

Answer choices:

Yes / No

The section starts by investigating whether ship-owners felt that they should have also been consulted in the fuel availability review. This highlights whether ship-owners were concerned with issues surrounding the availability of compliance fuel, that they felt the need to have also been part of the review.

Question 17:

Would your company have preferred the implementation date put back to 1 January 2025?

Answer choices:

Yes / No

As the outcome of the review led to the implementation of the global sulphur regulation on 1 January 2020, respondents were asked if they would have preferred the implementation date delayed to 1 January 2025. This highlights the number of ship-owners who may have wanted more time to decide on the solution to implement. It therefore indicates the preparedness of the industry in complying with the regulation.

Question 18:

IMO indicates that refineries can produce sufficient amounts of compliant fuel oils. However, a supplementary study by Ensys indicate potential problems for refineries to meet the demands. Does this affect your company's decision-making process in using low sulphur fuel as a solution to meet the 2020 deadline?

Answer choices:

Yes / No

As covered in **Chapter 3.4.3**, a supplementary study that was not commissioned by the IMO indicated potential problems for refineries to meet global shipping demand for compliance fuel. This study contradicts the findings from the IMO commissioned review which claimed refineries were able to produce sufficient amounts of compliant fuel oils (CE Delft, 2016).

Due to uncertainties surrounding the availability of compliant fuel, it is therefore important to investigate if it had an impact on ship-owner's decision-making process in using low sulphur fuel as a solution to meet the 2020 regulation. The responses would therefore, indicate the number of ship-owners who were undecided on using low sulphur fuel to comply with the regulation. This meant that these ship-owners may have to consider other solutions, which may include adopting technological products.

Question 19:

Is your company worried about price fluctuations of low sulphur fuel?

Answer choices:

Not worried / Not quite worried / Somewhat worried / Quite worried / Worried

It is also important to investigate if ship-owners are worried about price fluctuations of low sulphur fuel (LSF); brought about by uncertainties in its availability, which may then cause refineries to supply it at a premium rate (IEA, 2016). Fluctuations in the price of LSF may result in ship-owners to reconsider their decision on using LSF as a solution. This may then lead to ship-owners to look for other solutions, such as investing in scrubber systems that would provide them with more certainty.

As such, the level of how worried ship-owners are on price fluctuations of LSF, indicates how this may have an impact on their decision-making process in selecting LSF as a solution for the regulation.

Question 20:

Apart from costs and availability of low sulphur fuel, what other factors are your company taking into consideration when deciding on solutions to meet the 2020 regulation?

Answer choices:

(Open-ended question)

As an open-ended question, respondents were then asked to list down all other factors they were taking into consideration when deciding on a solution to comply with the sulphur regulation. These factors represent what ship-owners considers to be important to look for in a solution that would be implemented on their fleet. The responses to this question may have a bearing on the type of solution ship-owners were likely to adopt: either using alternative fuel or adopt technological products.

Question 21:
How likely do you think the shipping industry as a whole will be able to meet the lower sulphur requirements before 1 January 2020?
Answer choices:
Unlikely / Quite unlikely / Neither unlikely nor likely / Quite likely / Very likely

The section then seeks to investigate how likely respondents felt the shipping industry would be able to meet the sulphur regulation by the implementation date. This is based on compliance challenges. The results would highlight whether respondents felt the 2020 deadline was sufficient time for the shipping industry to comply with the regulation.

Question 22:
How strictly do you think the shipping industry will enforce the low sulphur regulations on 1 January 2020? (Enforcement level from Port, coastal and Flag State authorities).
Answer choices:
Strict / Quite strict / Neither strict nor lenient / Quite lenient / Lenient

As the 2015 ECA regulation was not strictly enforced by relevant authorities (Molloy, 2016), respondents were asked on how strictly they felt the 2020 sulphur regulation would be enforced. The aim of this question is to investigate whether ship-owners felt the regulations would be strictly enforced. If the regulation were to be strictly enforced, ship-owners would have to comply before the implementation date to avoid penalties.

If the regulation were not strictly enforced, some ship-owners may continue to burn heavy fuel oil; emitting high level of sulphur oxides into the air. Some ship-owners may also consider unenforced regulation as an opportunity for them to delay implementing measures, as there would be no consequences for non-compliance.

As such, responses to this question may have some bearing on the likelihood of the shipping industry to be in compliance with the regulation by 2020.

The questionnaire then moves on to the next section on the sulphur cap deadline of 1 January 2020. The aim of this section is to understand the level of preparedness of the shipping industry to comply with the regulation by the deadline.

Question 23:

How affected is your company's operations between now and 2020 with regards to the sulphur cap deadline of 1 January 2020?

Answer choices:

Unaffected / Quite unaffected / Neither unaffected nor affected / Quite affected / Affected

The section starts by asking respondents how affected their company's operations would be between now and 2020, with regards to the impending sulphur cap deadline. The answer to this question highlights the extent at which the sulphur regulation has affected the shipping industry, and whether changes would be made on ship's operations to comply with the regulation.

Question 24:

How prepared is your company to be able to meet the lower sulphur cap deadline of 1 January 2020?

Answer choices:

Unprepared / Quite unprepared / Neither unprepared nor prepared / Quite prepared / Prepared

Respondents were then asked on the level of preparedness of their company to comply with the sulphur regulation. This would highlight whether ship-owners were ready to meet the regulation by the deadline. Depending on the level of preparedness, it may also indicate whether ship-owners may have decided on a solution to implement on their ships.

Question 25:

Based on the deadline of 1 January 2020, your company:

Answer choices:

is taking its own efforts to be in compliance / will wait and see what the industry selects

In order to investigate whether ship-owners were taking their own initiatives to decide on the solution for their ships, respondents were asked to indicate if their company were either taking its own efforts to comply, or they would wait and decide based on what the industry selects. This highlights whether ship-owners would put in their own efforts and decide on the solution that suits their fleet or risk implementing a solution that may not be best suited for their ships.

Therefore, this would indicate whether ship-owners were taking the regulation seriously, or they were not perturbed by the regulation that they were willing to delay and wait for an outcome from the industry.

Question 26:

If your company is waiting for an outcome from the industry, how long will you be willing to wait before making a decision?

Answer choices:

End of 2017 / End of 2018

Respondents who indicated that their company would wait and decide on a solution based on what the industry selects, were then asked to indicate until when they would be willing to wait for an outcome from the industry, before they decide on a measure to adopt. This would indicate to what extent ship-owners were willing to delay implementing a solution on their ships. The longer ship-owners were willing to wait, the shorter the time would be for them to implement the measures across their entire fleet before the deadline.

The questionnaire then moves on to the next section on retrofitting scrubber units. The purpose of this section is to investigate the use of technological product as an alternative solution that ship-owners can adopt to comply with the regulation. As such, this section covers some of the key issues related to adopting scrubber systems as a solution which ship-owners need to consider. The results allow the researcher to make assumptions on the reason(s) why ship-owners may decide to implement scrubber systems to comply with the regulation, or vice versa.

Question 27:

Retrofitting scrubbers onboard requires ships to be in dry-dock for a period of time, resulting in the ship being off-hire. Does this affect your company's decision-making process in choosing scrubbers?

Answer choices:

Affected/ Unaffected

As scrubber systems needs to be retrofitted onboard, ships are required to be placed on off-hire for a period of time to allow for the installation process to be carried out. Respondents were therefore asked to indicate whether this affected their decision on selecting scrubber units.

The aim of this question is to investigate whether placing the ship on off-hire is a factor that affects ship-owner's decision to adopt scrubber systems, as revenues are not earned throughout the entire duration of the off-hire period.

Question 28:

As the 2020 deadline nears, how concerned are you with the availability of repair docks or dry-docks for the installation of scrubbers?

Answer choices:

Unconcerned / Quite unconcerned / Neither unconcerned nor concerned / Quite concerned / Concerned

Respondents were then asked to indicate on how concerned they were with regards to the availability of repair docks for the installation of scrubbers as the 2020 deadline nears. The aim of this question is to investigate whether ship-owners were concerned with the possibility that there may not be enough repair dock spaces available for them to install scrubbers. This may be brought about by the surge in the number of ship-owners deciding to install scrubber systems nearing to the deadline; thus, resulting in shortages of repair dock spaces.

Question 29:

Will your company pay more for a proven technology (certainty and quality) or opt for cheaper, unproven technology?

Answer choices:

Pay the bare minimum / Pay more for certainty and quality

Aside from scrubber systems, there are other technological products that ship-owners can adopt to comply with the sulphur regulation. This include using sail technology and solar technology to power ships. With a range of technological solutions available, it is important to investigate whether ship-owners were willing to pay more for a product that is proven with certainty and quality or opt for a cheaper and unproven product. The results would indicate ship-owners attitude towards their efforts to be in compliance with the sulphur regulation.

Question 30:

Is your company considering scrapping ships early as a solution to meeting the lower sulphur regulations?

Answer choices:

Yes / No

Other than to use alternative fuels or adopt technological products to be in compliance with the sulphur regulations, respondents were asked if they would consider scrapping their ships early. This is a key factor for ship-owners to consider when adopting technological products, as it may not be practical for them to retrofit ships that are nearing its end of life expectancy. The scrubber system is a prime example, where it is more practical as a long-term investment due to the high costs Involved.

Respondents that answered ‘No’ were directed to the last section of the questionnaire (Question 32). Otherwise, they were directed to the next question.

Question 31:

What are the factors that affect this decision? (Please tick all that apply)

Answer choices:

- Costs of retrofitting ships with scrubbers
- The value of the ship
- Ship's age
- Ship's trading patterns
- Costs of engine's modification
- Other (please specify)

Respondents were then asked to indicate all the factors that contributed to their decision to scrap their ships early. This would highlight the key factors that ship-owners were taking into consideration before deciding to scrap their ships.

The last section of the questionnaire covered the solution(s) that would be or had been implemented by ship-owners on their ships to comply with the global sulphur regulation. The aim of this section is to identify the solution(s) ship-owners had already decided on, investigate the reason for its selection, and discover the challenges faced throughout the process. For these reasons, this section was only applicable to respondents who had already chosen a solution to meet the 2020 low sulphur regulations.

Question 32:

Has your company chosen a solution to meet the 2020 low sulphur regulations?

Answer choices:

Yes / No

The first question in this section was to identify respondents who have decided on a solution, from those that have yet to decide. Respondents who answered

‘No’ were directed to the end of the questionnaire (Question 40), as they have not met the criteria to answer the questions in this section. Respondents who answered ‘Yes’ were directed to the next question in this section.

Question 33:
What solution have your company implemented or will be implementing to meet the low sulphur deadline of 2020?
Answer choices:
(Open-ended question)

Respondents were then asked to list down the solution(s) they had implemented or would be implementing to comply with the sulphur regulation. The aim of this question is to identify all the solutions that were selected by ship-owners. This then allowed the researcher to discover the most preferred solution by ship-owners.

Question 34:
Please can you briefly explain the reason(s) behind this solution.
Answer choices:
(Open-ended question)

Respondents were then asked to briefly provide an explanation for deciding on the chosen solution to implement on their ships. The aim of this question is to identify the reasons why the solution is selected. Based on the responses, the researcher would also be able to examine if there were any similarities in the reason a solution was selected by ship-owners. This may highlight the advantages of the solution. This information may be useful for ship-owners that have yet to decide on a solution for their ships. The data may also be applied to other solutions that were not selected by ship-owners, in order to examine the possible reasons behind it.

Question 35:

Did your company conduct a design and feasibility study when it comes to deciding on the solution to meet the low sulphur regulations? (Please briefly explain the reason(s) behind it).

Answer choices:

(Open-ended question)

Respondents were then asked to indicate whether they had carried out a design and feasibility study as part of the process of selecting a solution for their ships. The aim of this question is to investigate whether ship-owners adopted the solution based on their observation of current trend in the industry, or through doing their own research. Through the reasons provided, the researcher would be able to determine ship-owner’s attitude towards their efforts to comply with the regulation.

Question 36:

Are there any difficulties involved or do you foresee any difficulties when it comes to implementing your solution(s) to meet the low sulphur regulations?

Answer choices:

Yes / No

Respondents were then asked to indicate if they foresee or had encountered any difficulties when it came to the process of implementing their selected solution.

Question 37:

If you answered yes, can you briefly explain the difficulties?

Answer choices:

(Open-ended question)

Respondents who answered ‘Yes’ were asked to explain the difficulties involved. The aim of this question is to identify potential challenges associated with the solution. This information may be useful for other ship-owners when deciding on a solution to comply with the sulphur regulation, and it prepares them for what lies ahead should they select it.

Question 38:

Enforcement level varies from country to country. Did the potentially low standard of enforcement by some countries (port, coastal, flag state authorities) affected your decision-making process when selecting your chosen solution?

Answer choices:

Yes / No

Respondents were then asked to indicate if the potential level of enforcement of the sulphur regulation had any influence on their decision-making process of selecting a solution.

Respondents who answered ‘Yes’ were directed to the next question, while respondents who answered ‘No’ were directed to the end of the questionnaire (Question 40).

Question 39:

Can you briefly explain why a low standard of enforcement would affect your decision-making process?

Answer choices:

(Open-ended question)

Respondents were then asked to explain the reason enforcement level of the sulphur regulation had an influence on their decision-making process. The aim of this question is to investigate whether varying enforcement level affected the type of solution ship-owners would implement on their ships.

All respondents were then directed to the last question in the questionnaire.

Question 40:

Have you got any other comments or feedback regarding this questionnaire?

Answer choices:

(Open-ended question)

Respondents were invited to provide comments or feedback they may have regarding this questionnaire.

7.2.3 Questions justification – Equipment manufacturer questionnaire

Question 1:

Please indicate your position within the company.

Answer choices:

Senior management / Mid management / Junior management / Technical staff / Other (please specify)

As with the ship-owner's questionnaire, the equipment manufacturer's questionnaire started off by asking respondents to indicate their position within their respective companies. This ranged from junior management to senior management level, technical staff and 'other' positions, where respondents need to specify.

Getting to know each respondent's position within their company is also important in this questionnaire, as it informs the data collector on the validity and reliability of the information given. The higher the respondent's position is within the company, the more likely the information given is a true reflection of the overall view and direction of the company. It is still important to consider that some of the responses may be the personal views of the respondent, which may or may not correspond with the overall views of their company.

The first section of the questionnaire covered questions related to the company's background. The aim of this section is to investigate the core products being offered by the company.

Question 2:

Is the main product of your company offered to ship-owners so that they will be in compliance with the 2020 global low sulphur regulation?

Answer choices:

Yes / No (Please briefly explain why your company is offering this product to ship-owners?)

Respondents were asked if the core product offered by their company were meant for ship-owners to comply with the sulphur regulation. Respondents who answered 'No' were further asked to explain the reason for offering ship-owners with the product, as this would highlight the specific market for the product. They were then directed to the next section of the questionnaire (Question 4).

The aim of this question is to investigate whether the company was set-up for a specific market segment or that the company was tapping into a new market segment.

Question 3:

Please briefly give more information about why your company is offering this product?

Answer choices:

(Open-ended question)

Respondents who answered ‘Yes’ were asked to explain the reason their company was offering regulatory compliance products to ship-owners. Responses to this question would indicate the drivers that led the company into this business.

After respondents had a chance to state the main reason for their product offering, the next section of the questionnaire covered more specific questions to investigate the drivers of product innovation. The aim of this section is to identify all the factors that encouraged manufacturing companies to innovate.

Question 4:

What made your company decide to get into the market of providing ship-owners with products to comply with the 2020 regulation? (Please tick all that apply).

Answer choices:

Regulation from governing bodies such as the IMO / Demand from ship-owners / Corporate Social Responsibility (CSR) / Other (please specify)

Respondents were asked to select all the factors that encouraged their company to innovate based on the options given. Two of the options, regulation and demand, were extracted from the literature review (Lohmuller, 2004; Ghisetti *et al.*, 2017), while CSR was included as an option to investigate if it had any role in encouraging manufacturing companies to innovate. Respondents were also asked to specify the factors that drives innovation in their company should it not be listed in the answers.

The aim of this question is to investigate if any of these specific factors encouraged companies to innovate so that they could offer ship-owners with products to comply with the 2020 regulation.

Question 5:

Please rank the following from 1-4, with 1 being the most important factor that would influence your company to introduce a new product innovation in the market.

Answer choices:

Regulation from governing bodies such as the IMO / Demand from ship-owners / Corporate Social Responsibility (CSR) / Other (please specify)

Respondents were then asked to rank the options based on the most important to the least important factor that influenced their company to innovate and enter their products in the market. The options were ranked from 1 to 4, with 1 being the most important factor. The aim of this question is to investigate the key driver of innovation within manufacturing companies.

The next section of the questionnaire covered matters pertaining to products development, which include approval and certification process. The aim of this section is to investigate if the process involved in product innovation were easy and straightforward or difficult and challenging. Highlighting these processes may shed a light on potential challenges manufacturing companies faced when innovating. Solutions to overcome these challenges could then be discovered and applied to manufacturing companies to encourage further product innovation.

Question 6: What led your company to initiate a development project to test the technology for removing or reducing SOx from ship's emissions? **Answer choices:** *(Open-ended question)*

Respondents were first asked to explain the reason their company initiated a development project for a product that could reduce or remove sulphur oxides (SOx) from ship's emissions. The aim of this question is to investigate the reason for company's involvement to innovate in such a product. Responses to this question would highlight the reason manufacturing companies entered this market segment, which may as a result of technology push (Baumol, 2002; Horbach, 2008).

Question 7: How easy is it to get approval/certification from relevant classification societies on your product? **Answer choices:** Easy / Quite easy / Neither easy nor difficult / Quite difficult / Difficult

It is important for any new products introduced in the market to get the necessary approval and certification from relevant classification societies. This is to ensure the product's quality, safety and efficiency when being installed and used, conforms to specific and relevant standards. As such, respondents were asked to indicate how easy or difficult it was to get approval or certification for their products, in general, from relevant classification societies.

The aim of this question is to investigate if the process of seeking approval and certification was an easy task for manufacturing companies to achieve. If the process involved is difficult, it may discourage other manufacturing companies from innovating; thus, affecting the level of innovation in these companies.

Question 8:

How easy is it for your product to conform to IMO regulations or other regulations?

Answer choices:

Easy / Quite easy / Neither easy nor difficult / Quite difficult / Difficult

Respondents were then asked to indicate on how easy or difficult it was for their products to conform to IMO regulations or other regulations. The aim of this question is to investigate if the process of innovating a product to meet IMO regulations is either easy or difficult. Responses to this question would highlight whether the standards set by the IMO was difficult for manufacturing companies to achieve through their product innovation.

The next section of the questionnaire covered matters related to the drivers of product innovation. The aim of this section is to investigate the variables that drives or restricts manufacturing companies to innovate. These variables were investigated in the context of competition, government support, capital, market demand, social environment and corporate social responsibility (CSR).

Question 9:

What makes your company's product stands out form the rest?

Answer choices:

(Open-ended question)

Respondents were first asked to specify the key feature of their product that makes it unique from other related products in the market. The aim of this question is to investigate if manufacturing companies have developed a product that is similar or different from their competitors. This would highlight whether competition exists among companies when developing a product, to the extent that competition may be a driver of product innovation within manufacturing companies.

Question 10: What do you feel are the biggest challenges for the marine equipment sector in the next few years? (Please tick all that apply). **Answer choices:** Volatility in the price of materials / Global economy / Overseas competition / Brexit / Other (please specify)

Respondents were then asked to indicate all the factors that would affect their ability to innovate in the next few years. The aim of this question is to discover the variables that restricts manufacturing companies from innovating. Responses to this question would therefore highlight the constraints faced by manufacturing companies, which may have an impact on the number of new product innovations being introduced in the market.

The following three questions in this section of the questionnaire aims to investigate the impact government support has on innovation levels within manufacturing companies.

Question 11:

As a company, how important is it to receive government support before you consider investing in new technology?

Answer choices:

Unimportant / Quite unimportant / Neither unimportant nor important / Quite important / Important

As Shi *et al.* (2016) found that strong support from governments greatly encouraged innovation, respondents were asked to indicate on the level of importance of receiving government support when investing in new technology. The aim of this question is to investigate if government support has any influence on innovation activities within manufacturing companies.

Question 12:

Do supporting actions from governments, such as providing incentives and concessions, have a direct impact on the growth of your company in terms of new innovations?

Answer choices:

Yes / No (Please briefly explain what the government could have done to support new ventures in your company?

In a more direct question, respondents were then asked to indicate whether incentives and concessions provided by governments encouraged them to innovate. Responses to this question would indicate whether government support is a driver of product innovation within manufacturing companies.

Respondents who answered 'No' were then directed to Question 14, after explaining the role governments could play that would encourage them to innovate more. This would further determine if receiving any form of government support would encourage manufacturing companies to innovate. Respondents who answered ‘Yes’ were directed to Question 13.

Question 13: Please briefly explain and provide examples of the supporting actions provided from the government. **Answer choices:** *(Open-ended question)*

Respondents who were encouraged to innovate based on receiving government support were then asked to explain and provide with examples of the support they received. Responses to this question would highlight the specific factors that encouraged manufacturing companies to innovate.

The following four questions in this section of the questionnaire aims to investigate the impact company’s capital has on innovation activities. Innovations are capital oriented and without the availability of capital, the company would not be able to purchase land, machine and raw materials for the production of goods; thus, affecting its ability to innovate (Emmanuel, 2010). Depending on the scale of the project, the capital required could be a significant amount.

Question 14: *“Innovations are capital oriented. Without the availability of capital, the entrepreneur (organisation) would not be able to purchase land, machine and raw materials for the production of goods”*. To what extent do you agree with this statement? **Answer choices:** To a very large extent / To a large extent / Somewhat / To a small extent / To a very small extent

Respondents were first asked to indicate the extent to which they agree innovations are capital oriented. The aim of this question is to investigate if capital has an influence on innovation activities within manufacturing companies.

Question 15:
Is the availability of capital affecting your company's investment in new innovations?
Answer choices:
Yes / No (Please briefly explain how your company is financing for new innovations?

Respondents were then asked to indicate if their company's innovation activities were affected by their availability of capital. Responses to this question would determine whether capital is a factor that encourages or restricts product innovation within manufacturing companies.

Respondents who answered 'No' were then directed to Question 17, after explaining how their company finances new product innovations. The aim of this question is to identify how manufacturing companies are financing new innovations without relying on capital. Responses to this question may represent the solutions for manufacturing companies to overcome financial barriers.

Respondents who answered 'Yes' were directed to Question 16.

Question 16:
If finance is a problem, please briefly explain the measures your company is taking to overcome the financial barrier.
Answer choices:
(Open-ended question)

Respondents whose innovation activities were affected by their availability of capital were then asked to explain the measures they took to overcome their financial barriers. Responses to this question would indicate alternative ways to support innovation activities within companies. These solutions may then be used to encourage other capital-restricted companies to innovate.

Question 17:

How is your company planning to fund growth over the next few years? (Please tick all that apply)

Answer choices:

Cash reserves / Cash flow finance / Asset finance / Equity / Joint venture / Trade finance / Debt / IPO / Not planning / Other (please specify)

Since finance and capital are important factors influencing company's ability to innovate, respondents were asked to indicate how their company planned to fund their growth over the next few years. Responses to this question would highlight measures manufacturing companies took to support their future ventures such as investing in new innovations.

The following three questions in this section of the questionnaire aims to investigate the impact market demand has on innovation activities within manufacturing companies.

Question 18:

To what extent does market demand affect the supply of innovation?

Answer choices:

To a very large extent / To a large extent / Somewhat / To a small extent / To a very small extent

Respondents were first asked to indicate the extent to which they felt market demand affects the supply of innovation. The aim of this question is to identify if market demand is one of the factors that either encourages or restricts product innovation within manufacturing companies.

Question 19: Does market demand for a particular technology influence your company's decision to enter the market? **Answer choices:** Yes / No (Please briefly explain your company's reason for not entering the market)

Respondents were then asked to indicate if market demand for a product would encourage their company specifically to innovate and enter the market. Responses to this question would highlight the number of respondents whose company would innovate according to the demands of the market.

Respondents who answered 'No' were directed to Question 21, after having explained the reason for their company to not innovate based on market demand. The aim of this question is to discover if there are factors other than market demand that encourages companies to innovate.

Respondents who answered 'Yes' were directed to Question 20.

Question 20: Please briefly explain why your company is influenced to enter the market. **Answer choices:** *(Open-ended question)*

Respondents who indicated that market demand influenced their company to innovate were then asked to explain the reason behind it. The aim of this question is to discover the underlying reason to why manufacturing companies were innovating based on market demand.

The following three questions in this section of the questionnaire aims to investigate the impact social environment has on innovation activities within manufacturing companies. Social environment in this case refers to the ethical value system of the society, cultural values and role expectations of a company as expected by the society.

Question 21: To what extent do you think social environment has an impact on encouraging innovation? **Answer choices:** To a very large extent / To a large extent / Somewhat / To a small extent / To a very small extent

Respondents were first asked to indicate the extent to which they felt social environment impacted innovation. The aim of this question is to investigate the extent to which social environment is seen as a driver of innovation among manufacturing companies.

Question 22: Does social environment affect innovation activities within your company? **Answer choices:** No / Yes (Please briefly explain how it affect your company?)

Respondents were then asked specifically if social environment affects innovation activities within their respective companies. Responses to this question would highlight the number of respondents who innovates based on social environment. Respondents who answered ‘Yes’ were further asked to explain how it has affected their company. This would highlight whether social environment resulted in increased innovation within these companies.

Question 23: How important are social environmental factors on encouraging innovations within your company? **Answer choices:** Unimportant / Quite unimportant / Neither unimportant nor important / Quite important / Important

In order to further determine if social environment is one of the drivers for new innovations within manufacturing companies, respondents were asked to indicate how important social environment is in encouraging them to innovate.

The next question in the questionnaire seeks to investigate the impact company’s corporate social responsibility (CSR) has on innovation activities.

Question 24: Does your company’s Corporate Social Responsibility (CSR) influence the level of innovation within your company? **Answer choices:** No / Yes (Please briefly explain)

Respondents were asked to indicate whether their CSR had any influence on innovation activities within their respective companies. The aim of this question is to investigate if CSR is considered as one of the drivers of innovation by manufacturing companies. Respondents who answered ‘Yes’ were further asked to explain how it has influenced their innovation activities. Responses to this question would highlight whether companies were innovating more because of their CSR.

The last two questions in the questionnaire seeks to investigate if respondents considered their product (for ship-owners to comply with the 2020 global sulphur regulation) to be the first of its kind within their market segment. The aim of these two questions is to determine whether having a first-mover advantage encourages manufacturing companies to innovate. This is because a first-mover advantage allows a company to gain competitive advantage over other companies through control of resources. It also allows the company to establish a strong brand recognition and customer loyalty before other companies in the market starts to rise.

Question 25: Do you consider your company to be a first-mover within your market segment (with regards to introducing new technology in complying with the 2020 global low sulphur regulations)? **Answer choices:** Yes / No

Respondents were first asked to indicate whether they considered their respective companies to have a first-mover advantage.

Respondents who answered ‘Yes’ were directed to the next question, while respondents who answered ‘No’ were directed to the end of the questionnaire (Question 27).

Question 26:

If you answered yes, how much risk is your company willing to accept when introducing new innovation?

Answer choices:

High / Moderately high / Moderate / Moderately low / Low

Respondents who considered their company to be a first-mover within their market segment were then asked to indicate on the amount of risk their company was willing to accept when introducing new innovation. This is because being a first-mover brings with it the ‘free-rider’ effect, where secondary or late-movers to the market segment can study the techniques and strategies of the first-mover. In other words, competitors could gain, and they would not incur the ‘innovation costs’ which the first-mover has to sustain. This may also cut into the profits first-mover company would otherwise benefit.

All respondents were then directed to the last question in the questionnaire.

Question 27:

Have you got any other comments or feedback regarding this questionnaire?

Answer choices:

(Open-ended question)

Respondents were invited to provide comments or feedback they may have regarding this questionnaire.

7.2.4 Questionnaire testing and finalisation

In both set of questionnaires, each question was worded as simply and as clearly as possible without losing the specific meaning. This was taken into consideration when formulating the questions to avoid misinterpretation of what was being asked from respondents. Draft versions for both set of questionnaires were handed out to several respondents, from various backgrounds, for a trial run. It was also circulated to the researcher's acquaintances in the shipping industry.

Questions were modified, where necessary, based on the comments and feedbacks received from respondents in the trial run, before a final version of the questionnaire was created. The reason for conducting the trial run was to ensure that the received meaning corresponded as much as possible to the intended meaning. Furthermore, the time taken by respondents to complete the questionnaire and their reactions to the length of the questionnaire were also noted and taken into consideration. This is because it is crucial to keep the process as short as possible to avoid respondents losing their interest and patience. This was done without losing the intended outcome of the fieldwork.

The final version of both set of questionnaires were then subjected to further checks. Ship-owner's questionnaire set was vetted and checked by Craig Eason, an editorial director at Fathom Maritime Intelligence. Eason was selected as he is one of the leading journalists in the global maritime industry with a key focus on the operational, technical and regulatory trends. The finalised version of the questionnaire was approved after a few revisions and amendments were made to the original copy.

As for the equipment manufacturer's questionnaire, it was vetted and checked by the Director of Studies and Supervisors who were involved in this study. The finalised version of the questionnaire was approved after a few revisions was made to the original copy. This includes wording some of the questions in more detailed to allow respondents to better understand the context of the question being asked; ultimately resulting in a more detailed responses from respondents.

7.2.5 Survey sampling

As the focus area of this study is only limited to the European Union (EU), the population for ship-owner's questionnaire consisted of companies that were based within the EU. Seeking respondents for the ship-owner's questionnaire was done by gathering data online from two sites, which listed shipping companies within the EU. The marine information portal, '*infomarine24.com*', was one of the sites used to gather the data. This portal has a comprehensive list of ship-owners and operators globally. The list of shipping companies, sorted by country alphabetically, span eight pages long with approximately 180 companies per page. Companies recorded as belonging to EU countries were selected as the basis of sampling (see Appendix A for the full list). The other marine information portal used was *'ezlion.com'*, which lists 13 companies categorised as *Europe ship owners*.

The total number of companies gathered from this search was 172 based from the two sites mentioned above. As the total population for ship-owners based within the EU is unknown and unknowable, the value of 172 is regarded as a proxy of the population size (shipping companies operating within the EU countries) which are the focused of this research.

The decision was made to contact all 172 companies on the list for the ship-owner's questionnaire. The benefit of this strategy was that it maximised the findings of this research and assisted in strengthening the results. Adopting this strategy also allowed the data collector to compensate for non-responses and/or small number of returns (Saunders *et al.*, 2009). According to Easterby-Smith *et al.* (2008), a response rate of 20 percent is considered good. It is inevitable that a full 100 percent response rate will not be received from respondents. This is due to various reasons such as their inability to participate; email for questionnaire participation being ignored; or the email being marked as spam or junk. Constant email reminders being sent out to respondents also will not guarantee their participation in the research questionnaire.

A decision was made to aim for a minimum sample size of fully completed questionnaires of at least 20 percent of the population of the 172 respondents, which amounts to a minimum of 35 respondents. This is based on Easterby-Smith *et al.* (2008), who states that a response rate of 20 percent is considered good.

On the basis of 35 sample size (20 percent), findings from the questionnaire could be used to make credible conclusions on the phenomenon being investigated, bearing in mind that this is qualitative and not quantitative research. However, it would still be dependent on the overall response rate of the questionnaire to make it a fertile ground for academic conclusions.

On the other hand, population for the equipment manufacturer's questionnaire were limited to manufacturing companies within Europe that offered ship-owners products to comply with the 2020 global low sulphur regulation and low carbon regulation. Respondents for this questionnaire therefore included manufacturing companies in the wind technology industry, scrubber manufacturers, and solar power providers. The list of companies was extracted online by doing a search for companies supplying the shipping industry with wind, scrubber and solar power technologies within Europe (see Appendix B for the full list).

The number of companies specialising in this field is small. This had an impact on the sample size for the equipment manufacturer's questionnaire. After consolidating all the potential respondents to participate in this research questionnaire, only a total of 24 manufacturing companies were identified. As the number of respondents identified were small, a strategy was adopted to conduct a total survey in order to maximise the findings of this research and to strengthen the results. As such, sample for this questionnaire included all 24 manufacturing companies that offered ship-owners with products to meet the low sulphur regulation. If more than half of these respondents participated in the questionnaire, the response rate is considered high enough to make conclusions on the phenomenon being investigated.

To summarise, the contact list for ship-owner's and equipment manufacturer's questionnaires were 172 and 24 respectively, which while not exhaustive is a good reflection of the population size of ship-owners and equipment manufacturers in the EU that were relevant for the purpose of this research. All the companies on the list were contacted.

7.2.6 Administration of the questionnaires

Both ship-owner's and equipment manufacturer's questionnaires were administered via email. Respondents to the respective questionnaires were given a link in the email to access the online questionnaire. The questionnaire was hosted by an online survey software called *SurveyMonkey*. In the invitation email, a cover letter was included which briefly explained the purpose of the research, indicated what the online questionnaire seeks to find, and stressed that all responses would remain strictly confidential and anonymous. Respondents were also informed of the approximate time it took to complete the online questionnaire.

Emails inviting ship-owners to participate in the online questionnaire were sent out at the beginning of August 2017. The number of returns recorded after three weeks were 24 respondents (14 percent), of which 17 respondents (10 percent) were valid for having fully completed the questionnaire. Initially, it was felt that this rate of return was sufficient as data gathered from this questionnaire were only used to determine whether ship-owners encouraged manufacturing companies to innovate. However, it was later realised that more responses needed to be gathered as the response rate of 14 percent was not close enough to the 20 percent response rate needed to be considered good (Easterby-Smith *et al.*, 2008). Achieving a higher response rate would further strengthen the results and increase the possibility for new data to be identified from the open-ended questions in the survey.

For these reasons, the ship-owner's questionnaire was made *'live'* again in March 2018. Email invitations were sent out to the remaining 148 respondents that had yet to complete the online questionnaire. In order to avoid spamming respondents' Inbox, respondents were given the option to opt out of reminder emails. Respondents were asked to reply to the email with the subject heading *'unsubscribe'* in order to be removed from future correspondence. However, no such emails were received. Responses to the questionnaire was recorded and after two to three weeks, a reminder email was sent out should no responses be received. In this occasion, a response rate of 18 percent (27 respondents) of the remaining 148 respondents was achieved, of which 15 responses (10 percent) were valid for being fully completed.

In total, 32 respondents (18 percent) out of the population of 172 respondents, fully completed the questionnaire. While Easterby-Smith *et al.* (2008) considered a 20 percent response rate to be good, other studies had identified even lower acceptable response rate (Sheehan, 2001; Hager *et al.*, 2003; Scott *et al.*, 2011). Studies by Olson (2000) and Sheehan (1996) have reported an acceptable response rate of 10 percent and 16 percent respectively. On this basis, the response rate for the ship-owner's questionnaire has been deemed acceptable.

As for the equipment manufacturer’s questionnaire, the email inviting respondents to participate in the research questionnaire were also sent out at the beginning of August 2017. The number of returns after three weeks was six respondents (25 percent) out of the sample size of 24. This is not statistically significant, especially if it is not known if the population has a normal distribution (Buglear, 2005). But, this research does not employ quantitative strategy where statistical representativeness is a prime requirement, it is a qualitative piece of research (Mays and Pope, 1995).

To summarise, the final valid responses for ship-owner’s questionnaire and equipment manufacturer’s questionnaire were 32 responses (18 percent) and six responses (25 percent) respectively.

7.3 Results and analysis

Data collected from both set of questionnaires were analysed using descriptive statistics using both Microsoft Excel and the software on which the online survey was hosted on (*SurveyMonkey*). The results are presented and structured based on the themes drawn from the data (see Appendix H [ship-owner’s questionnaire] and Appendix I [equipment manufacturer’s questionnaire] for complete results).

7.3.1 Ship-owner’s questionnaire

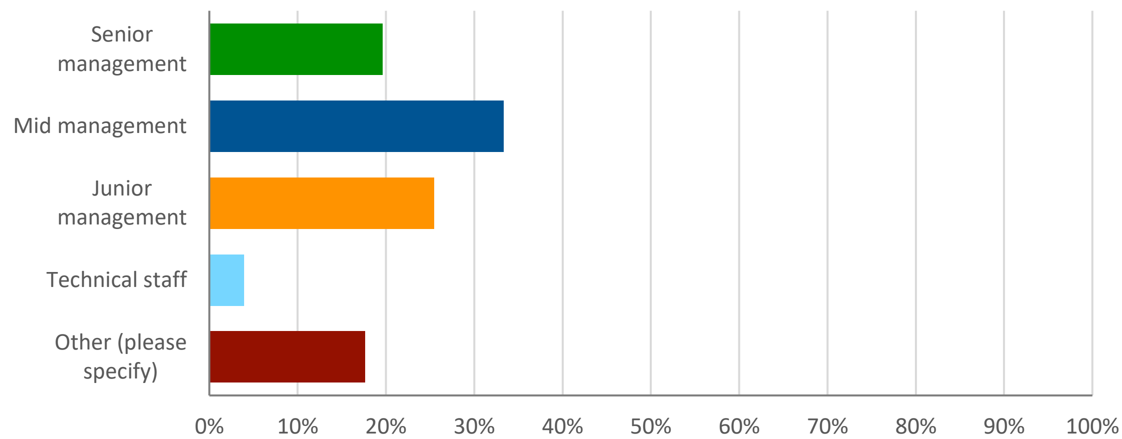


Figure 7-1 Respondents position within the company

The majority of respondents who took part in the ship-owner's questionnaire consisted of employees holding the position of mid management and above. This supports the validity and reliability of the data collected in the research questionnaire.

Other respondents also included employees from the customer service department and quality assurance/quality control inspector. Although these respondents do not hold managerial positions, their responses gathered from this questionnaire were equally as relevant and as valuable as other respondents. This is because the positions these respondents hold indicate they are in possession of certain level of knowledge and information on the company they are working for.

Measures implemented to meet SECA regulations (relates to Questions two to six)

Out of the approximately 60 percent of respondents who indicated that they have ships trading within the designated SECAs of the Baltic Sea or the North Sea, 27 percent of them indicated that their ships mainly trade in those areas.

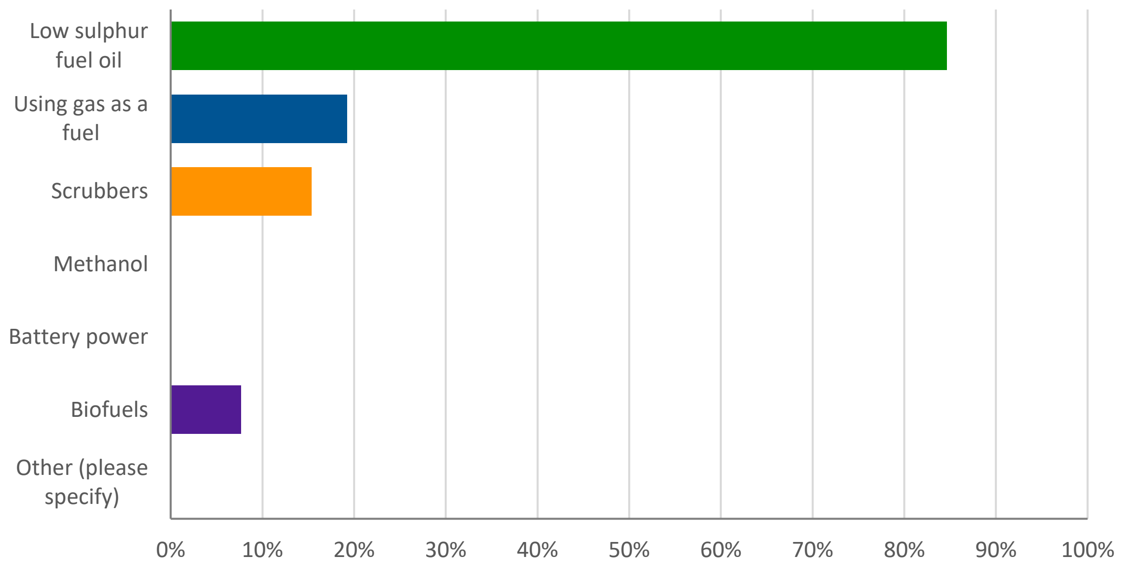


Figure 7-2 Measures to comply with 0.1 percent sulphur regulation (SECA)

Based on the results generated, low sulphur fuel oil was indicated as one of the solutions most implemented by ship-owners, at 85 percent, to comply with the 0.1 percent sulphur regulation when their ships traded within SECAs. Other solutions that were also implemented by ship-owners to meet the 0.1 percent regulation include the use of gas as a fuel (19 percent), the use of scrubbers (15 percent) and the use of biofuels (eight percent). As such, it is evident that low sulphur fuel oil is the most preferred solution for ship-owners to comply with more stringent sulphur regulation.

When respondents were asked whether they would employ the same solution to comply with the global sulphur cap regulation, the results found that 73 percent of respondents would employ the same solution while the remainder 27 percent of respondents indicated otherwise. As such, this shows that the most preferred solution that will be adopted and implemented by ship-owners to comply with the global sulphur cap in 2020 is using low sulphur fuel oil (based on **Figure 7-2**).

The 27 percent of respondents who would not be employing the same solution, are currently using low sulphur fuel. The reason given was they were considering using scrubber systems instead. As said by one of the respondents, their company was currently *“investigating the cost-benefit of using scrubber units”*.

The results indicate that these ship-owners may adopt scrubber systems to comply with the 2020 regulation if the cost-benefit of using the technology proves to be good. It is therefore evident that there are some ship-owners in the industry who are considering using scrubber systems to comply with the global sulphur limit. This may result in an increased number of scrubber units being installed, with a consequent decline in the usage of low sulphur fuel oil.

Measures implemented to meet EU sulphur directive (relates to Questions seven to 11)

54 percent of respondents are affected by the requirements under EU Directive 1999/32/EC, where ships at berth or anchorage in EU ports were obliged to use fuel with a maximum sulphur content of 0.1 percent. Of these, 21 percent of respondents have ships that mainly uses EU ports in the course of a month.

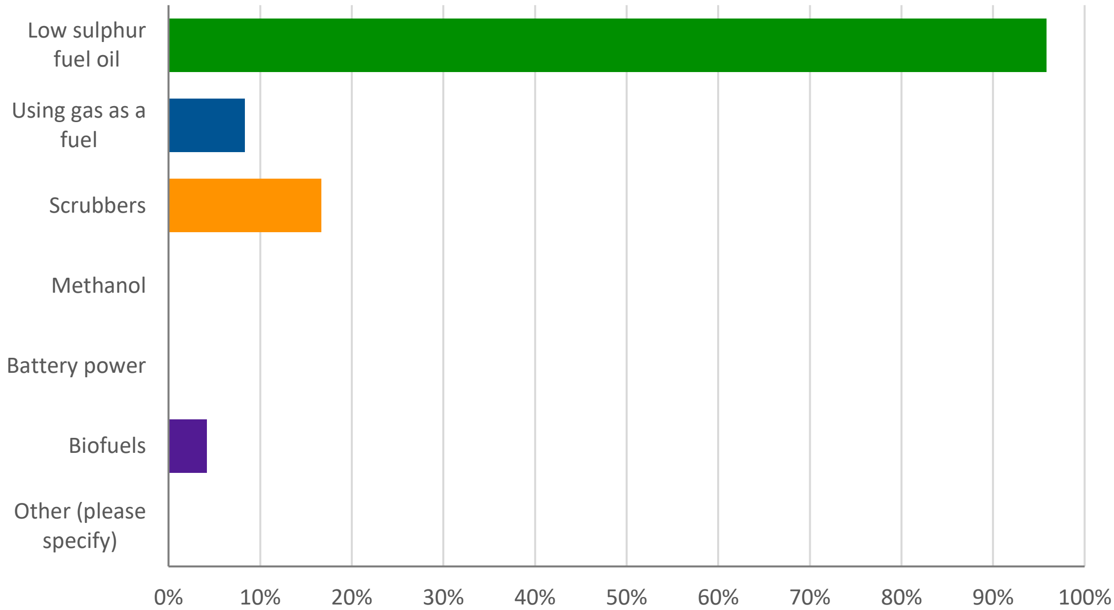


Figure 7-3 Measures to comply with 0.1 percent sulphur regulation (EU Directive)

Based on the results generated, low sulphur fuel oil was indicated as one of the solutions most implemented by ship-owners, at 96 percent, to comply with the 0.1 percent sulphur regulation when their ships used EU ports. Other solutions that were also implemented by ship-owners to meet the 0.1 percent regulation include the use of gas as a fuel (eight percent), the use of scrubbers (17 percent) and the use of biofuels (four percent). As such, it is evident that low sulphur fuel oil is the most preferred solution for ship-owners to comply with more stringent sulphur regulation.

When respondents were asked whether they would employ the same solution to comply with the global sulphur cap regulation, the results found that 75 percent of respondents would employ the same solution while the remainder 25 percent of respondents indicated otherwise. As such, this shows that the most preferred solution that will be adopted and implemented by ship-owners to comply with the global sulphur cap in 2020 is using low sulphur fuel oil (based on **Figure 7-3**).

The 25 percent of respondents who would not be employing the same solution, are currently using low sulphur fuel. The reason given was they were considering using scrubber systems instead. The same reason was given by respondents to Question six, which further indicates that ship-owners may adopt scrubber systems to comply with the 2020 regulation if the cost-benefit of using the technology proves to be good.

Potential future ECA (relates to Questions 12 and 13)

Based on the results generated, 46 percent of respondents indicated they would be affected by the spread of ECAs.

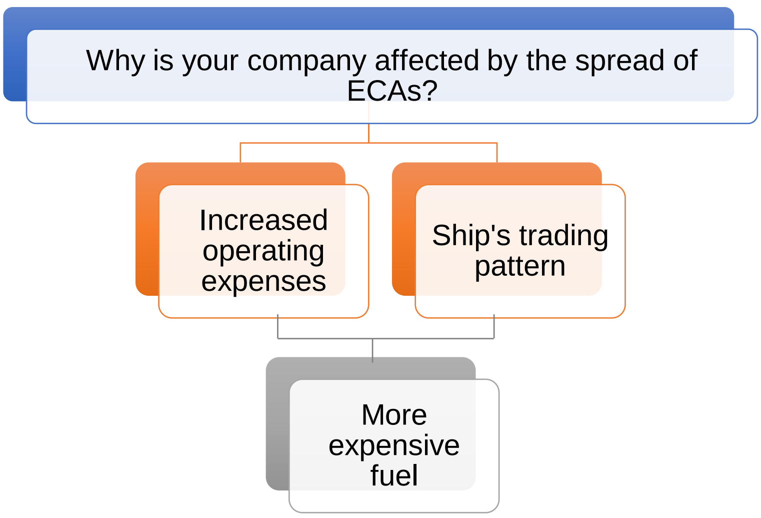


Figure 7-4 Reason companies affected by spread of ECA

This is because the spread of ECA would increase operating expenses and ship's trading patterns, which eventually meant that ship-owners would be paying for more expensive low sulphur fuel. However, one of the respondents said that when the global sulphur cap comes into force, the price difference between 0.5 percent fuel and 0.1 percent fuel may have no impact on ship-owners. In other words, the spread of ECAs may not have any significant impact on ship's operation.

Overall, 36 percent of respondents indicated that the potential spread of ECAs has an impact on their decision regarding adopting a solution to comply with the global sulphur cap.

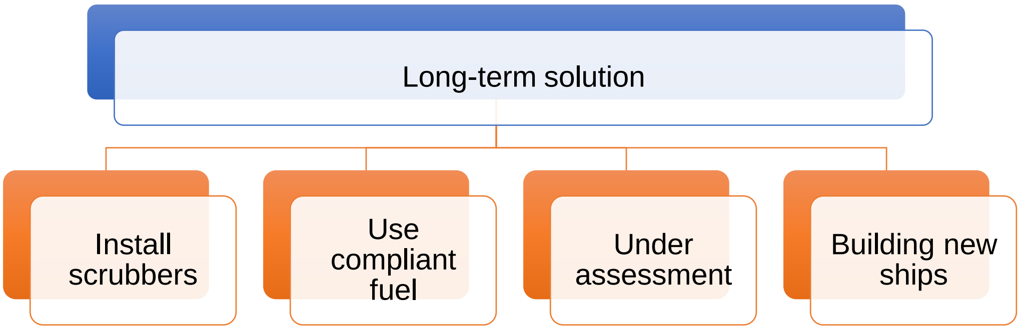


Figure 7-5 Long-term solutions to comply with global sulphur cap

These respondents indicated that their long-term solution to comply with the sulphur regulation would be to install scrubbers, using compliant fuel, currently under assessment and building new ships.

<u>Implementation date for sulphur regulation (relates to Questions 14, 15 and 17)</u>

65 percent of respondents indicated that the IMO had made sufficient efforts to consult with industry players before agreeing to reduce sulphur emissions in 2020. One of the respondents further highlighted that the low sulphur

requirements had been known in the shipping industry for *"quite some time"*, which therefore gave ship-owners ample time to be prepared.

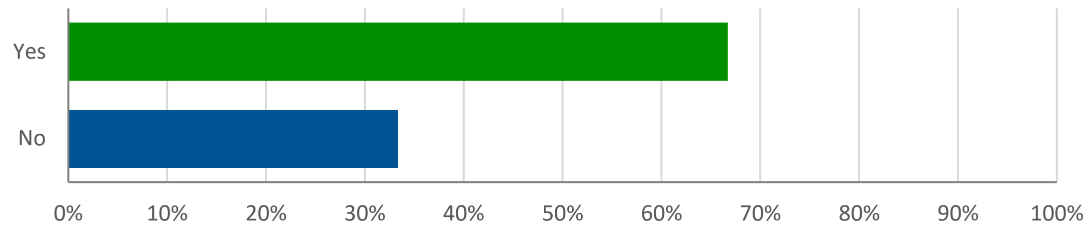


Figure 7-6 Number of respondents who preferred the implementation date put back to 1 January 2025

However, when it came to the implementation date of the sulphur regulation, 67 percent of respondents indicated that they preferred the enforcement date to be pushed back to 1 January 2025. This shows that the majority of respondents preferred more time to decide on a solution to comply with the regulation. Consequently, this may have an impact on the number of ships not complying by the implementation date, as ship-owners felt that sufficient time were not given.

<u>IMO fuel availability study (relates to Questions 16 and 18 to 20)</u>

The implementation date was decided by the IMO based on the outcome of the fuel availability study, which the majority of respondents (82 percent) felt that ship-owners should have also been consulted in the review. The results show that ship-owners were concerned with issues surrounding the availability of compliance fuel that they felt the need to have been involved. Their participation in the review could have potentially resulted in the implementation date of the regulation being delayed by five years to 1 January 2025.

Although the consortiums hired by the IMO found that there is sufficient compliant fuel oil to meet global shipping demands, an independent study not hired by the IMO, found contradicting results. Despite this, almost 70 percent of respondents indicated that their decision to use LSF was not affected. This shows that using low sulphur fuel is still the preferred solution by ship-owners to meet the regulation; despite the possibility of inadequate supply of the fuel to meet global demands.

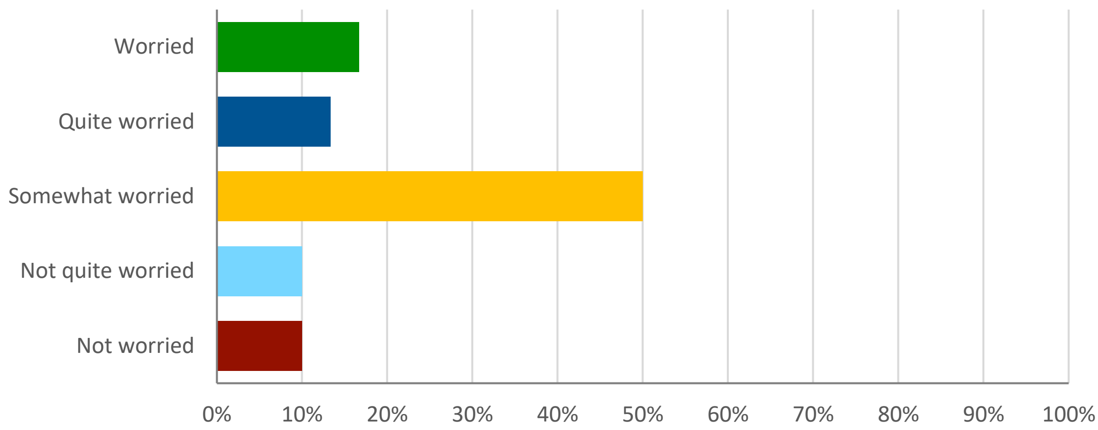


Figure 7-7 How worried respondents are on price fluctuations of LFS

Contradicting results on the availability of LSF to meet global shipping demand may result in price fluctuations of the fuel. With regards to that, the majority of respondents (50 percent) were ‘somewhat worried’ about price fluctuations of LSF. The results show that price fluctuations of LSF is not one of the key factors affecting ship-owners from using the fuel to comply with the sulphur regulation. Some ship-owners are also considering adopting scrubber units as a solution to meet the stricter air regulation. However, this would first involve looking into issues related to its availability, feasibility and onboard modification works required for its installation.

<u>2020 sulphur regulation enforcement (relates to Questions 21 and 22)</u>

When respondents were asked to indicate the likelihood of the shipping industry to comply with the sulphur regulation before 1 January 2020, the majority of respondents (30 percent) indicated ‘neither unlikely nor likely’. In other words, respondents were unsure whether the industry would be able to meet the regulation. As such, it could not be determined from the results whether respondents felt the 2020 deadline was sufficient time for the shipping industry to comply with the regulation.

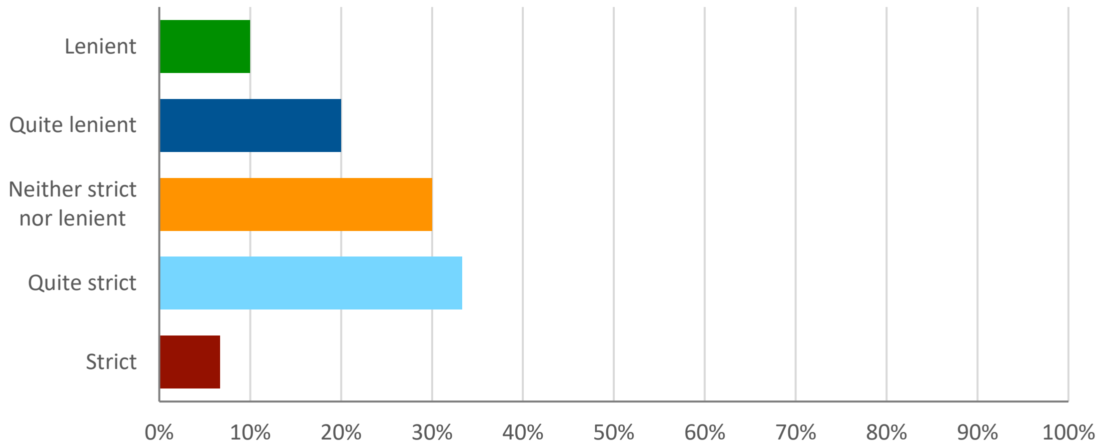


Figure 7-8 Sulphur regulation enforcement levels

However, the majority of respondents (33 percent) indicated that enforcement level for the sulphur regulation will be ‘quite strict’. The high level of enforcement indicated by ship-owners may reflect their on-going efforts to comply with the regulation, as they would not want to be penalised for non-compliance. This means that the likelihood of the shipping industry to meet the regulation by the implementation date is high.

<u>Preparedness to meet 2020 regulation (relates to Questions 24 to 26)</u>

When respondents were asked to indicate their preparedness in meeting the regulation, the majority of them answered that their company were ‘neither unprepared nor prepared’. This indicates that the majority of ship-owners felt that they may or may not be ready to comply with the regulation in 2020.

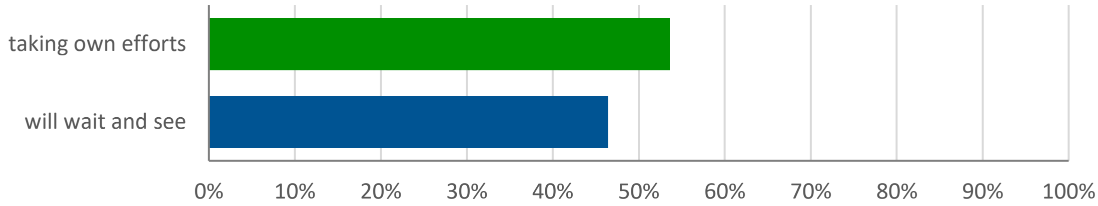


Figure 7-9 Respondents' initiatives on adopting a solution

However, in terms of initiative, 54 percent of respondents indicated that they are taking their own efforts to comply with the regulation, rather than waiting for an outcome from the industry. This shows that the majority of ship-owners are taking the regulation seriously, as they are putting in their own efforts to decide on a solution best suited for their ship's operation. Of the 46 percent of respondents who would wait for an outcome from the industry, more than 80 percent indicated they would be willing to wait until the end of 2018 before deciding on a solution. This means that there is a high possibility these ship-owners may not be able to comply with the regulation. This is due of the challenges and difficulties that ship-owners may face from implementing a solution at the last moment, such as inadequate dry-dock spaces to retrofit scrubber systems onboard.

<u>Installing scrubber units (relates to Questions 27 to 29)</u>

Ship-owners not intending to use low sulphur fuel to meet the 2020 regulation are considering adopting scrubber units. However, there are several factors that needs to be considered. Firstly, is placing ships on off-hire for the installation process. Based on the results, the majority of respondents (61 percent) indicated that placing their ships on off-hire affected their decision-making process in selecting scrubbers as a solution.

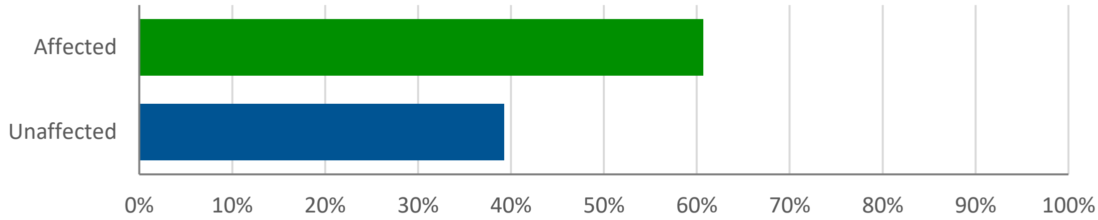


Figure 7-10 Respondents affected by placing ships on off-hire

As such, the number of scrubber units being installed by ship-owners as a solution to comply with the sulphur regulation, may not be significant. This means that some of those ship-owners may consider other options to implement on their ships.

Secondly, is the availability of repair docks or dry-docks to install scrubber units.

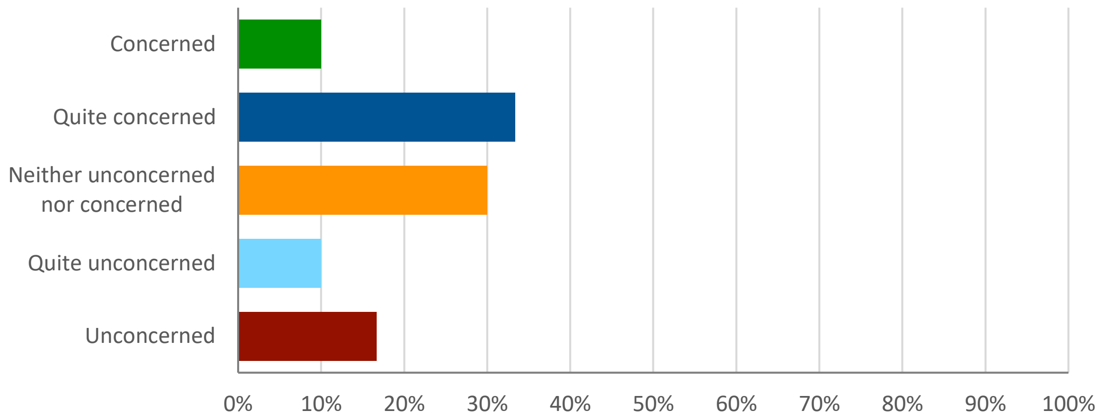


Figure 7-11 Level of concern ship-owners have on availability of repair docks or dry-docks

Based on the results, 33 percent of respondents indicated that they were 'quite concerned' with the availability of repair docks or dry-docks for scrubber unit installation. As such, the potential shortages of repair dock spaces may be considered as a factor affecting ship-owners to adopt scrubber systems as a solution to comply with the regulation. This may result in ship-owners to consider other solutions to adopt.

The last point to consider is regarding whether companies were willing to pay more for a proven technology (certainty and quality) or opt for cheaper, unproven technology.

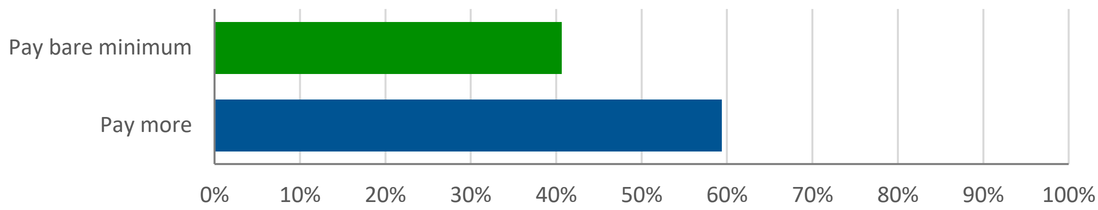


Figure 7-12 Percentage of respondents paying more or the bare minimum for technology

The results show that the majority of respondents (59 percent) were willing to pay more for a proven technology. This shows that the majority of respondents would rather invest in a product that is proven to comply with the regulation, than risk investing in a product that may not meet the requirements of the sulphur regulation. This is an indication that significant efforts are being put in by most ship-owners on selecting the best technology for their ships.

<u>Chosen solutions by respondents to meet 2020 regulation (relates to Questions 32 to 34 and 38)</u>

Out of all the participants of this research questionnaire, only 46 percent of them had chosen a solution to comply with 2020 regulation.

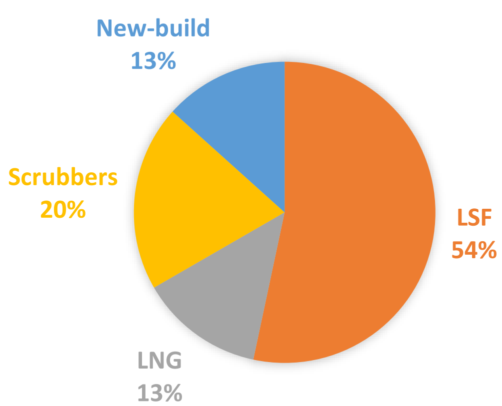


Figure 7-13 Solutions implemented to comply with 2020 regulation

Based on the results, the majority of respondents (54 percent) opted for low sulphur fuel. Other solutions include the use of scrubbers, building new ships and using LNG. It is evident from the results that using LSF is the most preferred option by ship-owners, while the use of technological products such as scrubber system is not as widespread.

Ship-owners decided to use LSF as it was the most practical solution that suits their ship's operations. Ship's age is another factor for using LSF as it is not justifiable for ship-owners to invest on ships that are nearing its life expectancy. Some of the respondents also said that retrofitting scrubbers was not a practical solution for their ships.

Ship-owners who opted for using scrubbers said that it made more economical sense to retrofit their new, modern ships with a long lifetime ahead, with the units. The use of LNG and building new ships which were also identified, was adopted based on the requirements and practicality of each individual companies.

Based on the responses, it is evident that each solution has its own set of advantages for it to be selected by ship-owners to comply with the sulphur regulation. In addition, some of the selected solutions may not be applicable for use by certain ships, such as installing scrubber units on ship's that are nearing its life expectancy. As such, there is no 'one solution fits all' option for ship-owners as each solution is applicable on a case-by-case basis.

The results also found that the potentially low standard of enforcement of the sulphur regulation had no impact on respondents' (71 percent) decision-making process on selecting a solution.

7.3.2 Equipment manufacturer's questionnaire

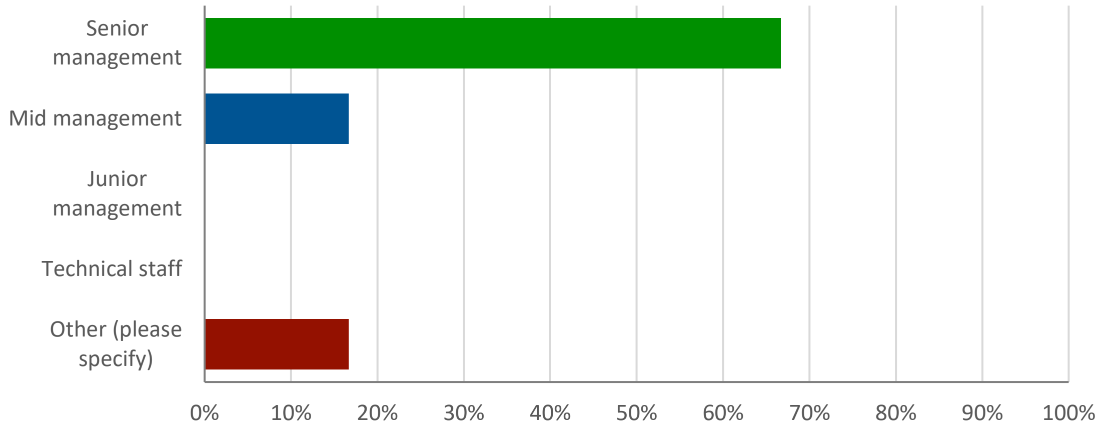


Figure 7-14 Respondents position within the company

The majority of respondents who took part in the equipment manufacturer's questionnaire consisted of employees holding the position of mid management and above. This supports the validity and reliability of the data collected in the research questionnaire.

Other respondents also included an employee from the marketing department. Although the respondent does not hold managerial positions, their responses gathered from this questionnaire was equally as relevant and as valuable as other respondents. This is because the position the respondent hold indicate they are in possession of certain level of knowledge and information on the company they are working for, especially when it comes to information regarding their products.

Drivers of product innovation (relates to Questions four to six)

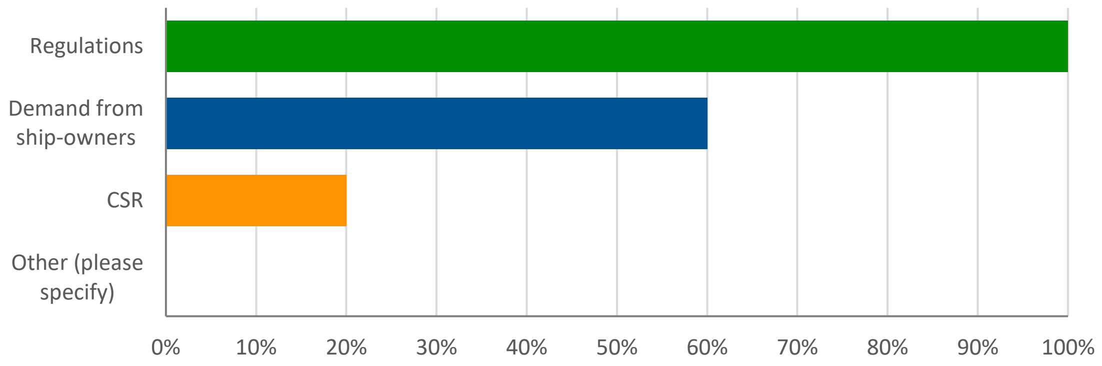


Figure 7-15 Reasons why companies entered market to offer products to comply with sulphur regulation

When respondents were asked to indicate their reasons for entering the market of providing ship-owners with products to comply with the 2020 regulation, all of the respondents selected ‘regulation’. It is evident from the responses that the key driver of product innovation is IMO regulation. Although demands from ship-owners may also be considered as a key driver of innovation (with more than 50 percent of respondents selecting it), CSR could not be considered as a key driver in this instance. This is due to CSR being indicated as a driver by only one fifth of the respondents.

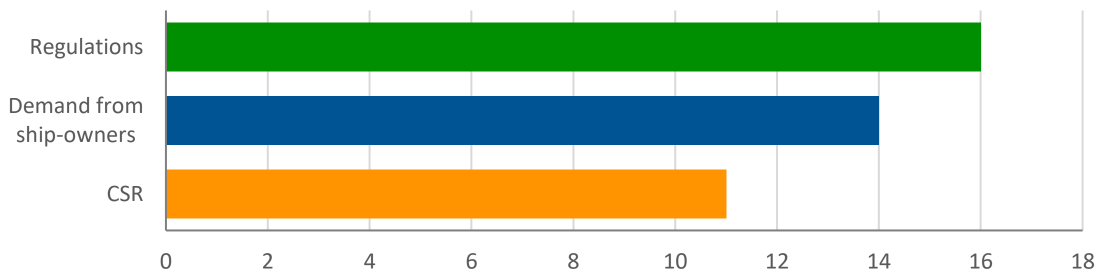


Figure 7-16 Drivers of innovation ranked from most to least important

When respondents were asked to rank the drivers for product innovation from the most important to the least important, regulation was ranked as the most important factor. This was followed by ship-owners demand and CSR. Therefore, it is evident from the results that IMO regulation is a key driver that encourages product innovation in equipment manufacturing companies within the European Union (EU).

Respondents were further asked to indicate the factors that led them to develop technologies capable of reducing SOx from ship's emissions. 'Previous experience', 'new regulation' and 'business opportunity' were identified as the factors. These factors can also potentially be categorised as the drivers of product innovation.

Market demand as driver of innovation (relates to Questions 18 to 20)

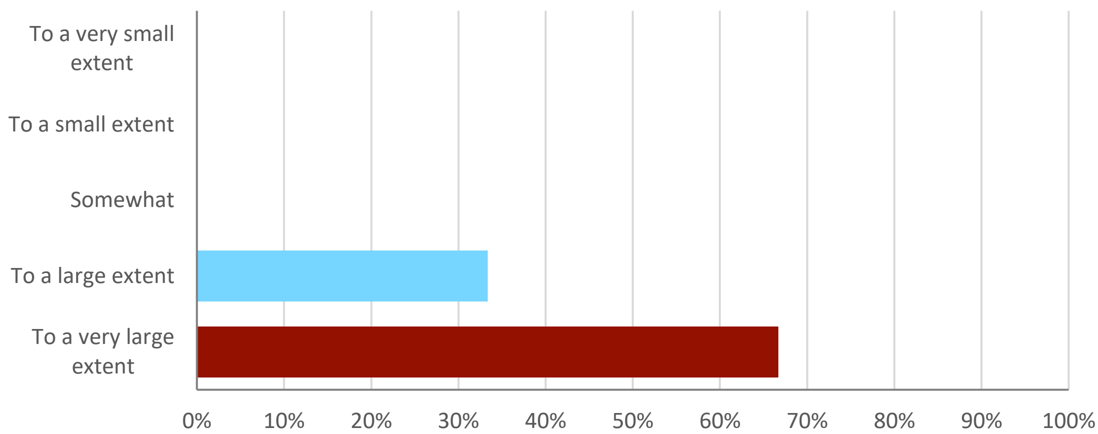


Figure 7-17 Extent to which market demand affect innovation supply

When respondents were asked to indicate the extent to which market demand affects the supply of innovation, the majority of respondents indicated 'to a very large extent'. The reason identified from the responses on why companies were influenced to enter the market based on demands was because of the opportunity it presented to them. It provided these companies with an opportunity to start a new venture to meet the demand, which may result in increased revenue.

From this, it is evident market demand has a strong influence on innovation activities within manufacturing companies. As such, market demand is considered as one of the key factors encouraging product innovation in manufacturing companies.

Social environment as driver of innovation (relates to Questions 21 to 24)

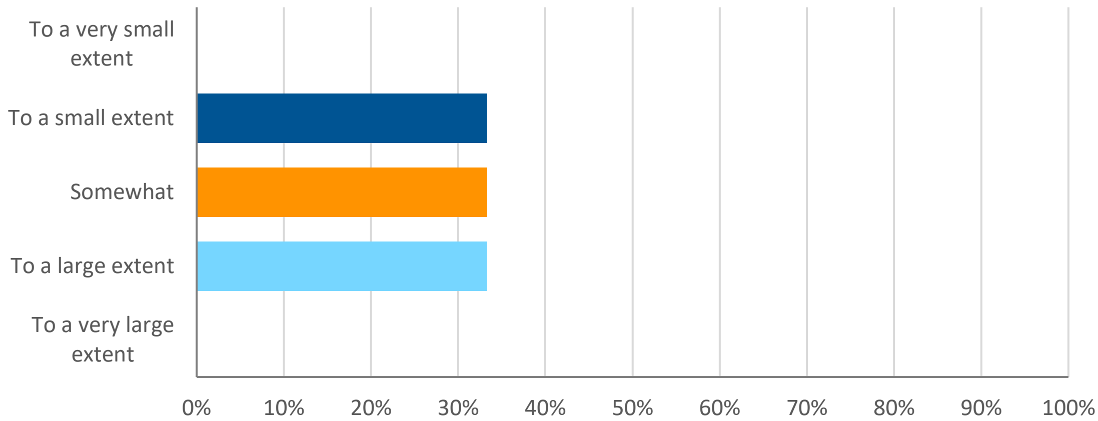


Figure 7-18 Extent to which social environment impact innovation

When respondents were asked on the extent, they felt social environment encourages innovation, their responses were split equally across ‘to a small extent’, ‘somewhat’, and ‘to a large extent’.

However, all of the respondents agreed that social environment affects innovation activities within their respective companies. One of the respondents said that the current social environment has encouraged their company to invest and develop in clean air technologies. Another respondent, whose company had dedicated the past 60 years reducing all types of air pollutions, said their company *“believes in helping the environment”* through their products. In doing so, the respondent said their company can contribute to future generations having better quality of living. Approximately 67 percent of respondents also indicated that social environmental factors were ‘quire important’ in encouraging innovations within their respective companies.

Based on these responses, it is evident that social environment encourages product innovation in manufacturing companies. As such, social environment can be considered as a driver of innovation.

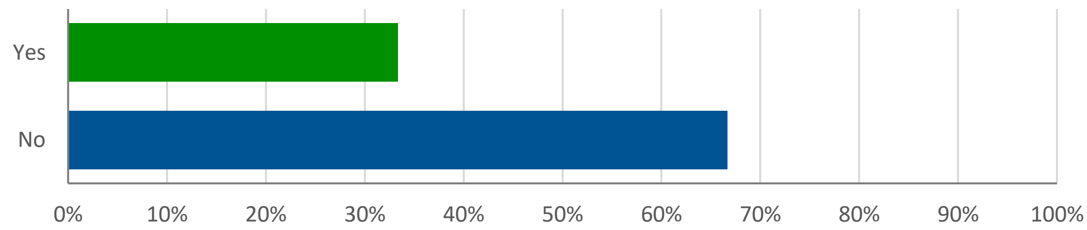


Figure 7-19 Percentage of respondents whose CSR influence innovation

Furthermore, 33 percent of respondents indicated CSR has an influence on the level of innovation within their respective companies. According to one of the respondents, this is because CSR is the general driver of product innovation for their company. As such, it is evident that although CSR is not a strong indicator of product innovation in manufacturing companies, it is still considered to be a driver of innovation.

Finance for innovation (relates to Questions 14 to 17)

The majority of respondents (50 percent) agreed 'to a large extent' that innovations are capital oriented, as companies need to have the financial means to purchase machines and raw materials for the production of goods. As such, it is evident that capital has an influence on innovation activities in manufacturing companies, where the lack of capital may restrict companies from innovating.

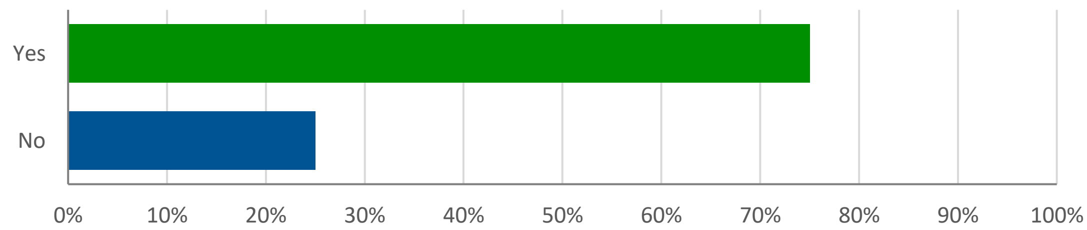


Figure 7-20 Percentage of respondents affected by availability of capital

When respondents were asked whether availability of capital affects their investment in new innovations, more than 70 percent of respondents indicated 'yes'. Based on the results, it is evident that availability of capital affects manufacturing companies from innovating. As such, capital here, is considered as a factor restricting product innovations in manufacturing companies.

Respondents were also asked to indicate the measures undertaken by their company to overcome financial barriers. Only two measures were identified from the responses provided. The two measures to finance new innovations are 'merger and acquisition' and 'strategic alliance'. As such, these are the solutions that may be used to encourage other capital-restricted companies to innovate.

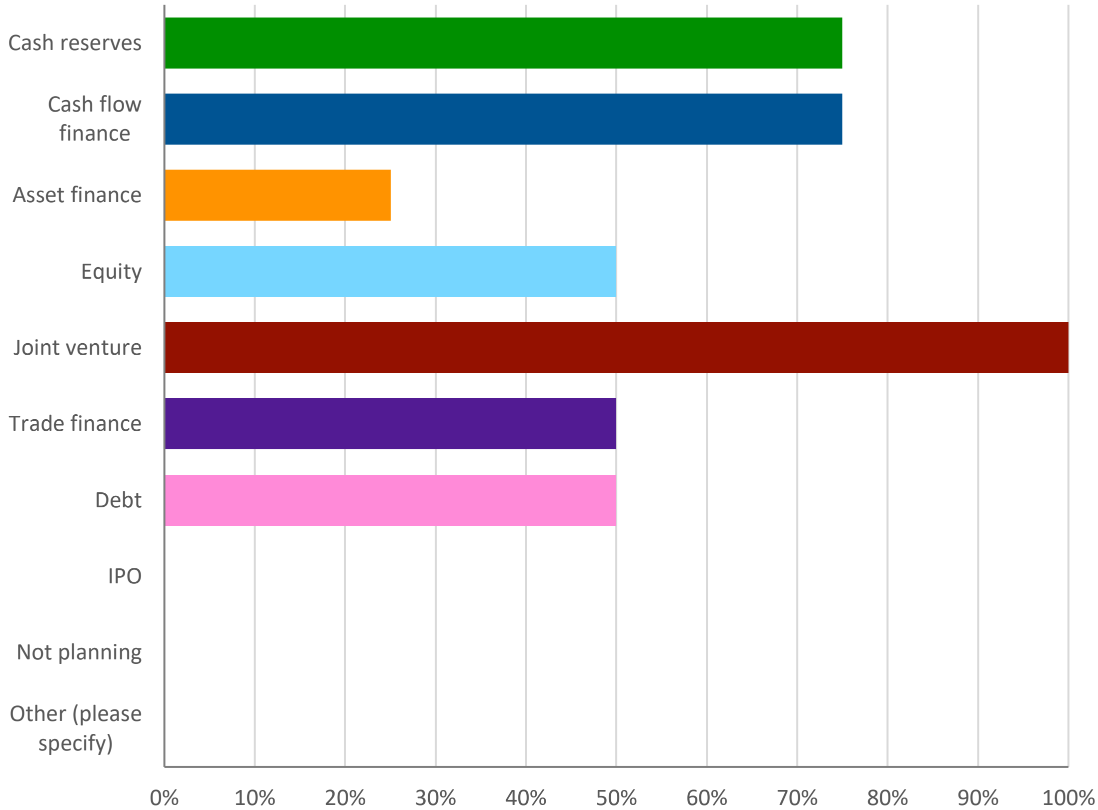


Figure 7-21 Measures to fund growth for innovation

Respondents were then asked to indicate the measures their company is undertaking to fund growth over the next few years. This may help overcome their financial restrictions to innovate. Based on **Figure 7-21**, all of the respondents selected ‘joint venture’ as a way of funding growth to support their innovation activities. All of the selected measures can also be considered as potential ways for manufacturing companies to overcome financial barriers.

Government support (relates to Questions 11 to 13)

Government support is another measure, identified from the literature review, that may help companies innovate.

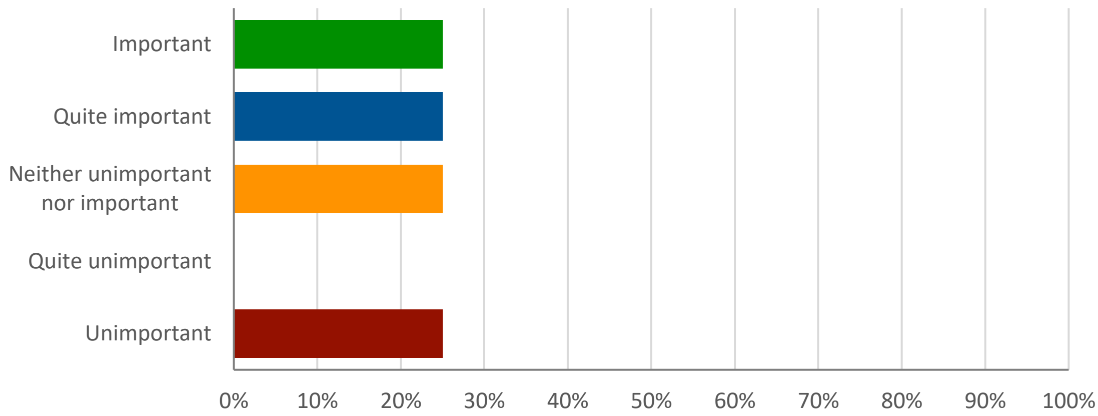


Figure 7-22 Level of importance on receiving government support

25 percent of respondents indicated that receiving government support is an ‘important’ factor that would influence their decision to invest in new technology. Based on **Figure 7-22**, it is evident that availability of government support has an influence on innovation activities within manufacturing companies. As such, government support is considered as one of the drivers of innovation.

Respondents were further asked whether supporting actions from the government has a direct impact on the growth of their company in terms of new innovations. The results found that half of the respondents indicated ‘yes’. However, some respondents highlighted that it was not the government’s responsibility to make available any form of support or incentives to encourage manufacturing companies to innovate. Nonetheless, it is evident from the results that supporting actions from governments, such as providing incentives, subsidies, grants, loans and concessions, do encourage some manufacturing companies to innovate.

7.4 Summary

This completes the analysis of data for stage one concerning the preferred solution implemented by ship-owners to comply with the global sulphur regulation and the variables that encourage or restrict product innovation within manufacturing companies. The analysis of data in stage two is shown in the next chapter.

CHAPTER 8 STAGE 2 DATA COLLECTION – INTERVIEWS

8.1 Introduction

This chapter covers the second stage of data collection, where a semi-structured interview was employed as a method to collect data. The layout of the chapter is as follows: development of interview questions, justification of interview questions, recruitment for interviews and conducting the interviews. Following that, the chapter presents the results and analysis of the interview before the chapter concludes with a summary.

8.2 Semi-structured interviews

This second stage of data collection aims to investigate further and identify the drivers of product innovation in the marine equipment sector. It is important to highlight that the two stages of data collection were conceived to be equal in merit. Each stage was a piece of research in its own right but complemented the other, to produce a bigger picture with greater insight than each stage alone.

Data generated from stage one of the data collection were used as a guide to formulate the questions for the semi-structured interviews. Data generated from the interviews were analysed using thematic content analysis, with the help of *NVivo* to organise, retrieve and present the data more effectively and coherently.

Although ship-owners had participated in stage one of the data collection (questionnaires), they were not involved in the second stage of data collection (semi-structured interviews). Only participants from the marine equipment sector within the EU and industry experts were involved in this stage. The reason behind this is because, the second stage of data collection aims to investigate further and identify the drivers of product innovation in the marine equipment sector, which is in line with the aim of this research. Therefore, ship-owners participation at this stage was not required as they did not fit the focus of the interview and the questions bearing no significance to them.

8.2.1 Development of interview questions

The questionnaires were analysed and the results from the analysis were then used to finalise the interview questions. This was done to allow the researcher to list questions to areas that required further and more in-depth investigation.

Results from the ship-owner's questionnaire, found that approximately 16 percent of ship-owners (based on **Figure 7-2** and **Figure 7-3**) had adopted scrubber technology to comply with stricter air regulations. As this indicates a demand for scrubber units, it is important to investigate further the impact this demand has on manufacturing companies' innovation levels. Results from the equipment manufacturer's questionnaire also found that market demand affects supply of innovation, which requires further investigation to understand the underlying reason. Regulations was also found to impact companies' innovation levels. These results from the questionnaires highlights the drivers of innovation and therefore, needs to be further investigated. Results such as these were used to guide the interview approach.

Based on the literature and the results of the questionnaires, a list of potential topics and issues to be discussed during the interview was then drawn up. This allowed the interviewer to ensure all grounds for the interview were covered and to ensure nothing was overlooked. Following that, the general areas for questioning were organised into order before addressing the wording of the questions.

The following topics form the structure of the interview:

- Drivers of innovation
- Finance for innovation
- The adoption rate of technology

These topics were only used as a guide to structure the interview due to the semi-structured nature of the interview. As such, the purpose of the list was not there for the interviewer to follow closely. In most cases, the focus of the interview can go in any direction, and the interviewer must be flexible with the questions asked. In situations where the interview process hits a 'snag', the interviewer can refer to the question list to get back on track.

8.2.2 Interview questions justification

In order to investigate the drivers of innovation further, the first part of the interview consisted of questions aimed at identifying the reason manufacturing companies were offering ship-owners with green technology. To avoid biased responses from participants, they were first asked to indicate what they thought were the main drivers of green innovation. Subsequent questions were then formulated based on the drivers of innovation identified from the equipment manufacturer's questionnaire. Therefore, the first part of the interview aims to identify the variables that encourage or restrict product innovation and to understand the reasons behind it.

Topic 1 interview questions	Origin of questions
Drivers of innovation	
1. Why are companies offering abatement technology to ship-owners?	1. Questionnaire results
2. What are the primary drivers to offer abatement technological products in the market?	2. Literature review
3. Does regulation from governing bodies, such as the IMO, have any impact on the level of innovation within companies?	3. Questionnaire results
4. Does Corporate Social Responsibility (CSR) have any impact on companies' investment in green technology?	4. Questionnaire results
5. Does market demand for a product affect companies' level of innovation?	5. Questionnaire results
6. What other drivers would encourage companies to invest more in green technology?	6. Literature review
7. What impact does competition among manufacturing companies have on the level of innovation in a company?	7. Literature review
8. What impact do new business opportunities have on the level of innovation in companies?	8. Questionnaire results

Venturing into a new business and the process of research and development requires capital. Depending on the project, a large amount of capital may be required by companies to fund their innovation activities. Results from the questionnaire also found that access to finance affects companies' innovation activities. Therefore, the second part of the interview consisted of questions aimed at investigating how manufacturing companies finance their product innovation activities and how they overcome financial barriers. Responses to these questions may highlight the difficulties or challenges involved in financing new product innovation. This may result in finance being identified as one of the factors restricting innovation activities within companies.

Topic 2 interview questions	Origin of questions
<u>Finance for innovation</u> 1. Does the availability of government support have any impact on companies' investment in new technology? 2. Does access to finance have an impact on companies' investment in new technology? 3. What are the ways to overcome financial barriers?	 1. Questionnaire results 2. Literature review 3. Questionnaire results

Based on results from the ship-owner's questionnaire, it was evident that technological solution was not the preferred solution by most ship-owners. As such, the last part of the interview consisted of questions aimed at investigating the reason for the slow adoption rate of technological products by ship-owners to comply with the global sulphur regulation. Responses to these questions highlight the issues equipment manufacturer companies need to address, to increase the adoption rate of technological products by ship-owners.

Topic 3 interview questions	Origin of questions
<u>The adoption rate of technology</u> 1. In your opinion, how did the shipping industry responded to the availability of technologies available to meet the 2020 regulation? 2. Has this response differed from your expectations? 3. What are the barriers to the implementation of emission savings technology on ships? 4. What is needed to overcome these barriers?	 1. Questionnaire results 2. Questionnaire results 3. Questionnaire results 4. Questionnaire results

8.2.3 Recruitment for interviews

Recruitment for the interviews was done by sending out emails to companies or businesses in the marine equipment sector, requesting their participation in the research. Sampling for the interview was not chosen to be different to the sample of the equipment manufacturer's questionnaire. This was due to the limited number of manufacturing companies within the EU that offered ship-owners with products to comply with air emission regulations. In the invitation email, a cover letter was included which briefly explained the purpose of the research, provided some of the sample questions and stressed that all responses would remain strictly confidential and anonymous. Participants were also informed of the approximate time to complete the interview process.

Emails were sent out to all companies involved in offering ship-owners with technological products to meet the low sulphur regulation. Therefore, this included all companies offering wind technological products, scrubber manufacturers, and solar power providers. This was done to maximise the possibility of securing a minimum of eight participants for the interviews, out of the 24 potential participants identified.

However, in anticipation of the low response rate for participation in the interview process, and in order to get a broader range of views, invites were also sent out to academics, groups and organisations involved in the promotion of green technological products for cleaner emissions from ships. This would compensate for the relatively small number of replies expected from the marine equipment manufacturers, and in helping to realise the minimum number of participants required for the interviews were met.

Table 8-1 shows the participants that were involved in the semi-structured interviews. All details that can be used to identify each interviewee has been omitted for anonymity and confidentiality, in line with this research's ethics and per the assurance given to participants in the invitation email.

Participants	Position	Category
Interviewee A	Chief Executive Officer	Industry expert
Interviewee B	Managing Director	Wind technology
Interviewee C	Director General	Wind technology
Interviewee D	Sales Manager	Scrubber technology
Interviewee E	Project Manager	Wind technology
Interviewee F	Senior Project Manager	Industry expert
Interviewee G	General Manager	Scrubber technology
Interviewee H	-	Industry expert

Table 8-1 Semi-structured interview participants

The total number of interviewees for this research is eight. Mays and Pope (1995) states that unlike in quantitative investigations, *"statistical representativeness is not a prime requirement* [in qualitative investigation] *when the objective is to understand social processes"* (p.110). Furthermore, the small number of participants *"will facilitate the researcher's close association with the* [interviewees]*, and enhance the validity of fine-grained, in-depth inquiry in naturalistic settings"* (Crouch and McKenzie, 2006, p.483). Similar study by Ehmann (2014) had five interviewees. As such, the sample size of eight interviewees is sufficient to draw the conclusions of the thesis.

8.2.4 Conducting the interviews

The interview process was conducted via Skype, which was felt to be appropriate and the preferred method amongst interviewees. This was due to the flexibility a Skype interview offered, where the interview could be conducted at a time and location which were convenient to each participant. Interviewing through Skype also benefited the interviewer. This is because the interviewer was no longer required to travel to and from different cities and countries within the European Union (EU) to conduct the interview. It would have otherwise been a challenging task for the interviewer to execute, due to the various locations within the EU where participants for the interview may originate from.

At the start of each interview process, the interviewee was first acknowledged for taking time off their busy schedule to participate in the research. General conversation was also made, such as asking the interviewee how their day has been. This acted as an 'ice-breaker' and allowed both interviewer and interviewee to establish an informal relationship. Furthermore, it also ensured the interviewee felt at ease and comfortable throughout the interviewee process.

The purpose of the research was then summarised to the interviewee. This was done in general terms similar to those mentioned in the email sent to them requesting for the interview. It was also expressed to the interviewee that their thoughts, opinions and experiences were of interest in this research. The interviewee's anonymity was also explained during the interview, along with how the data would be used.

During the interviewee process, misinterpretation of questions being asked may lead to inaccuracy in the responses. This could arise from poorly worded questions or from language barrier. Therefore, to avoid scenarios where interviewees provide answers different to the context of the question, they were encouraged to voice out and seek clarification at any point during the interview process. This allowed the interviewer to rephrase the question while keeping to the original context of the question. Furthermore, it was also essential to ensure interviewees did not get impatient and annoyed during the interview process. As such, the interview questions were asked in a clear and concise manner to the best ability of the interviewer throughout the interviewee process.

However, interviewing via Skype was not without its challenges. One of the main challenges faced during the interview process was connectivity. Connectivity issues were encountered when trying to establish a connection on Skype with some of the participants. The cause of this fault was down to low signal strength or poor wireless connection of either the interviewer or interviewee. This may be due to the distance from the Wi-Fi router or hotspot, or too many users on the network. In some instances, the Skype call connection was cut-off mid-way through the interview. Before the interview could proceed any further, the connection needed to be re-established.

At times, such issues encountered with connectivity was rectified by moving to a different location or area where the signal strength is stronger, or to turn-off unused devices for the time being. This required some time and effort which caused some inconvenience for both the interviewer and interviewee. However, there were instances when this solution did not rectify the issue. In that case, the interviewer had no other option but to use call credit on Skype in order to proceed with the interview.

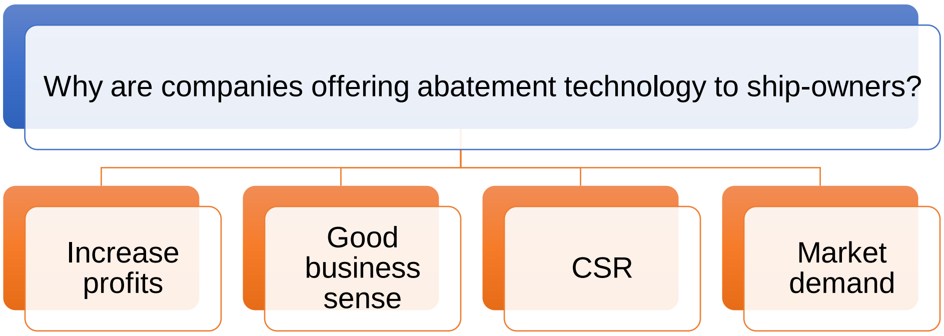
Poor connectivity encountered at certain times during some of the interview processes also affected the quality of the Skype call. This caused the Skype session to ‘freeze’, delay, and at times, affected the clarity of the voice projected through Skype. Each time this issue was encountered, either the interviewer or interviewee had to repeat what has last been said before the conversation was interrupted.

However, all the interviewees were understanding and accommodating when such issues arise, as they were well aware of the potential issues and difficulties involved with interviewing through Skype.

Each interview lasted between 30 minutes and 45 minutes. At the end of each interview, the interviewee was given a chance to highlight or bring up any questions they had or any last thoughts they wished to add regarding the interview.

8.3 Results and analysis

Question 1:



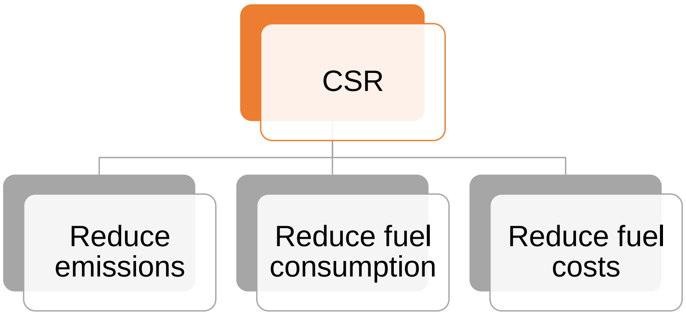
Four themes were identified from interviewees' responses when they were asked to explain the reason abatement technology were offered to ship-owners by manufacturing companies. The four themes are: 'increase profits', 'CSR', 'good business sense' and 'market demand'.

For the first theme, Interviewee G said that some companies, including their own, offers ship-owners with abatement technology in order to increase their profit margins; even if it meant entering a new market segment. The interviewee's company, which specialises in the inert gas system, decided to offer the scrubber system to their customers *"to make more money".* This was made possible as the inert gas system shares the same technology as the scrubber systems. The company, therefore, offered scrubber systems as they saw a market for the product and the *“potential for earning more money”* (Interviewee G).

Companies are also offering abatement technology to ship-owners as it makes a good business sense. According to Interviewee A, the world we are living in *“is circling towards a low or zero carbon emission and all other harmful emissions status”*. The interviewee further said that the shipping industry is *“so far behind the curve that it* [would] *be badly impacted if it does not start to act now because the change in technology is so fundamental”*. As such, manufacturing companies are offering ship-owners with abatement technology as it makes good business sense.

Also sharing this view is Interviewee C, whose company specialises in wind-based technological solutions. The interviewee said that *“wind is the most, and only immediately available free energy … which is technologically ready to be exploited* [and] *has enough energy density to propel a complete vessel”*. As such, the company saw that it made good business sense to offer ship-owner with wind-based technological solutions.

For the third theme, Interviewee D said that some companies offer abatement technology because it is their corporate social responsibility. According to the interviewee, there were companies, including their own, that offers ship-owners with abatement technology such as scrubber as “*it is part of* [their] *CSR”* to reduce harmful gas emissions. Interviewee B also offers ship-owners with abatement technology as their company wants to take part in helping the shipping industry to not only reduce its emissions but also its fuel consumptions and fuel costs.

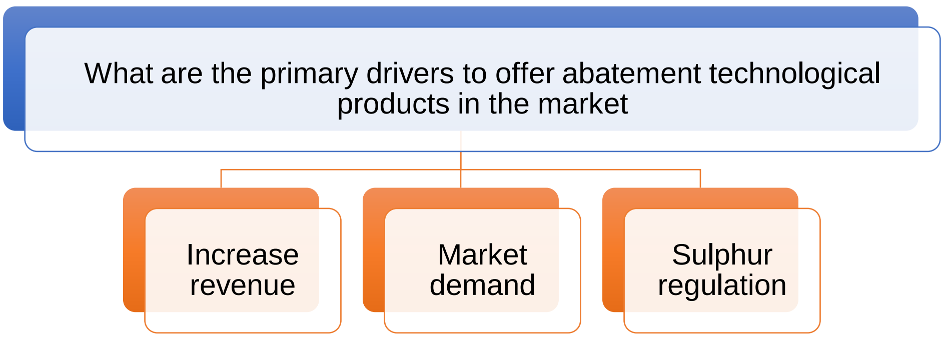


These factors have always been behind the company's drive to offer abatement technology in the market.

The last identified driver is market demand. According to Interviewee H, market demand is *"the main reason why companies offer ship-owners with abatement technology"*. Most companies in the market are *"always looking to see what is happening in the global industry and where the market is* [heading to]*"* (Interviewee E). These companies then innovate based on demand.

For Interviewee E, their company saw potential demand for commercial wind-sails in the market, which encouraged them to innovate and offer ship-owners with the product. According to the interviewee, *"it is worth entering the market early and being part of it from a blunt commercial point of view"*.

Question 2:



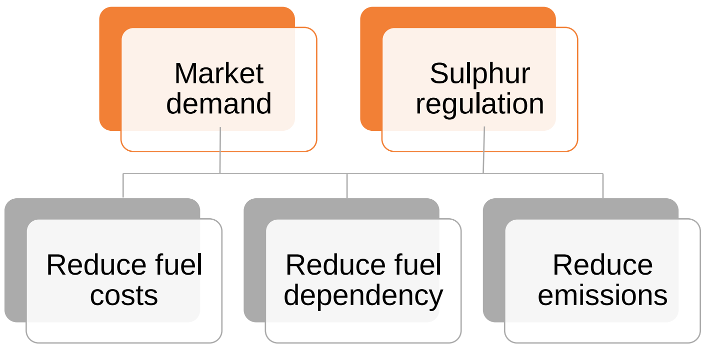
Based on the responses, three themes were identified: increase revenue, sulphur regulation and market demand.

The first identified driver is increased revenue. According to Interviewee A, most companies, if not all companies innovate and offer abatement products in the market to increase their revenues. The interviewee said that *“at the end of the day, it is all about making more money”.* This is because, companies need to plan and operate their business to be *“sustainable into the future”,* which meant that companies had to make money; otherwise they “*will not have a business”* (Interviewee A).

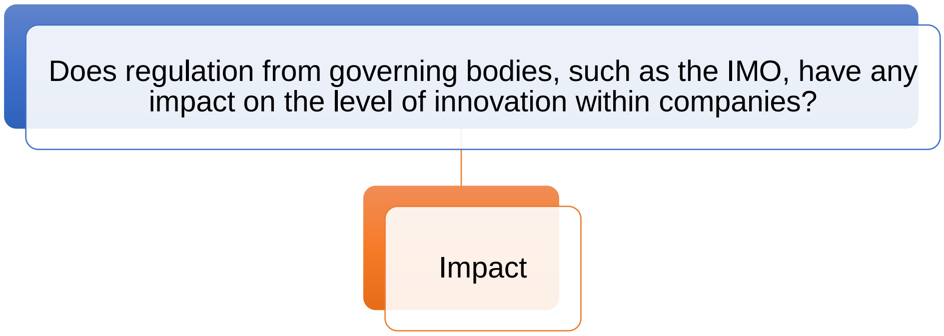
The second identified driver is sulphur regulation. Both Interviewee D and G said the sulphur regulation is the main reason manufacturing companies were offering ship-owners with abatement technology. This is to enable ship-owners to comply with the regulation.

The third and final identified driver is market demand. This demand derives from ship-owners need for a product capable of *“reducing their fuel costs, reduce their dependency on carbon fuel and reduce their emission levels”* (Interviewee H). According to Interviewee H, demand for products to meet those criteria was created by ship-owners as they need a product to comply with the 2020 sulphur regulation by the IMO. As said by Interviewee C, the sulphur regulation *“obliged every ship-owner to re-think maritime shipping”* that resulted in their demand for technological products.

As manufacturing companies are innovating to offer ship-owners with products capable of reducing fuel cost, fuel dependency and emissions based on demand and regulation, the two drivers can be seen interlinked to one another.



Question 3:



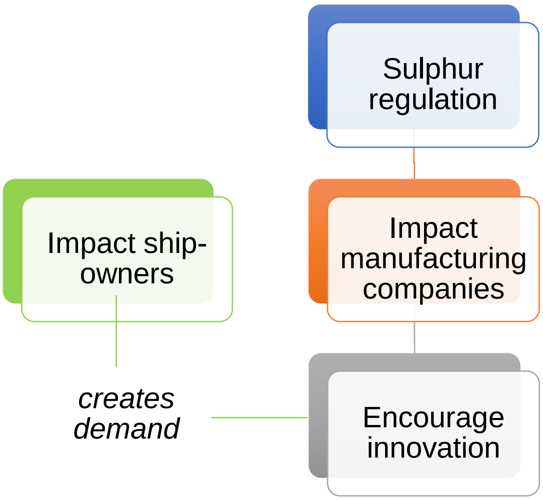
Based on the responses, all the interviewees said that IMO regulation, about the sulphur regulation, does impact innovation level within companies.

According to Interviewee F, the sulphur regulation *"encourages companies to innovate more"*. The sulphur regulation, *"driven by the IMO and supplemented by bodies* [such as] *the EU … advocating the same message"* (Interviewee G) is what encouraged more companies to invest in green technology. This is because these companies saw the potential opportunities it may bring for the company, such as *"increasing profits"* (Interviewee H). Subsequently, this may create competition among companies to have *"the best solutions"* (Interviewee G) in the market, which further increases innovation levels within companies.

Interviewee A said that implementation of the sulphur regulation had brought IMO a step closer to achieving its emission reduction goals. Before its implementation, the air emission policy, although *"really critical"* (Interviewee A), was *"very slow and unhelpful"* in pushing the industry towards reducing their emissions.

However, the fact that the policy is there does *"*[changes] *people's mind about how to interact with new technologies"* (Interviewee A).

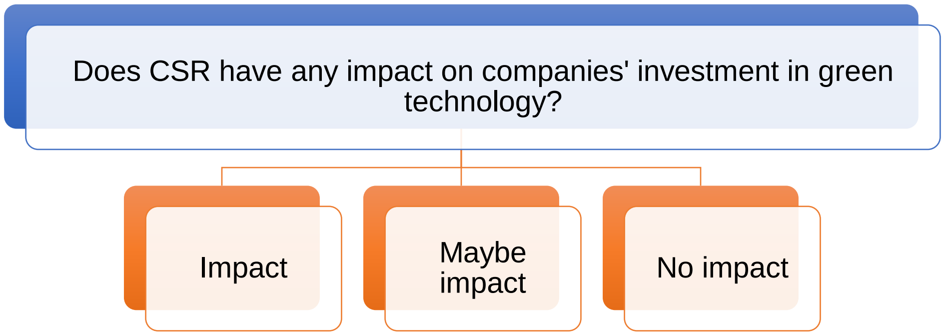
As such, ship-owners created the demand for new technologies when the policy was implemented; indirectly encouraging innovation from equipment manufacturing companies.



Implementation of the 2020 sulphur regulation *"has accelerated the uptake of low sulphur solutions"* (Interviewee A), as companies offering scrubber units had seen an increase in their business. This contributed to further demand for such products, which other companies were now encouraged to supply by innovating. The more IMO pushes ship-owners to reduce their emissions, *"the better it is for* [manufacturing companies]*"* (Interviewee E).

Interviewee C also said their company were encouraged to innovate based on demand from ship-owners. The sulphur regulation has forced ship-owners to *"move on to something"* to comply. This had *"strong impacts on* [the company's] *projects and* [their] *developments"* (Interviewee C).

Question 4:



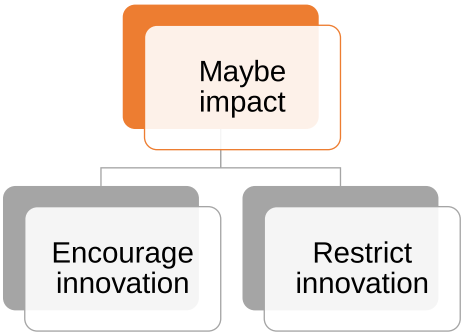
Three themes were identified from the responses when interviewees were asked regarding the impact CSR had on companies' investment in green technology. The three themes are 'impact, 'maybe impact' and 'no impact'.

For the first theme, 'impact', it was found that there were companies in the industry that innovates and invest in green technology mainly because of their CSR. According to Interviewee D, some companies, including their own, consider CSR as *"part of* [their] *company's policy"*. Some companies even consider CSR to be *"part of the DNA"* (Interviewee A) of their business. This contributed to these companies to constantly undertake research and development work to *"see how* [they] *could solve some of the environmental issues* [faced by] *the industry"* (Interviewee D).

Although Interviewee B also said that CSR encourages them to innovate, their company does not use such *"image-building-buzz-words"*. According to the interviewee, their company innovates because they feel responsible for their future. As such, companies such as this innovate and invest in green technology because they believed *"it is the right thing to do and it makes more money"* (Interviewee A) for the company.

As for the second theme, 'maybe impact', Interviewee F said that companies' CSR might not necessarily result in the company investing in green technology.

For some companies, CSR may either ‘encourage innovation’ or ‘restrict innovation’ in their company.

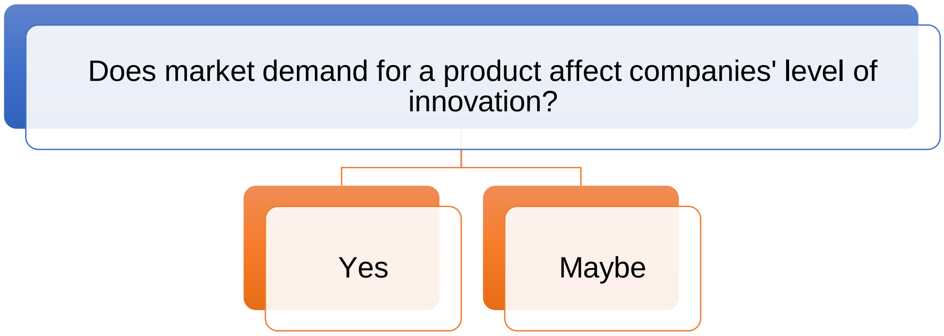


According to Interviewee F, there are some manufacturing companies that *“would need to understand the issue”* first and see how it could benefit them before it would result in investment in green technology. In other words, although the company may pledge to innovate based on environmental concerns, innovation would not take place if it is not something the company want to offer or can offer.

On the other hand, some interviewees said CSR has no impact on companies’ investment in green technology. Interviewee H said that most, if not all manufacturing companies have CSR policies. However, their investment in green technology is not directly affected by their CSR. Interviewee E said that companies’ drive to invest in green technology, may come directly from individuals from within the company who are pushing the company in that direction.

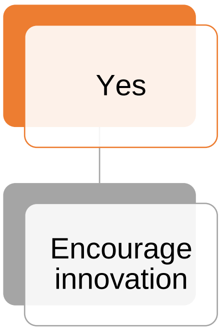
Also, Interviewee G said that instead of manufacturing companies’ CSR, it is ship-owners’ CSR that influences manufacturing companies’ investments in green technology. According to the interviewee, if a ship-owner’s CSR calls for their ships to be green, they would look for measures to meet those criteria. As such, ship-owners create the demand for green products in the market, which is supplied by equipment manufacturing companies.

Question 5:



Based on the responses, two themes emerged when interviewees were asked if market demand for a product affected companies' level of innovation. The two themes identified are 'yes' and 'maybe'.

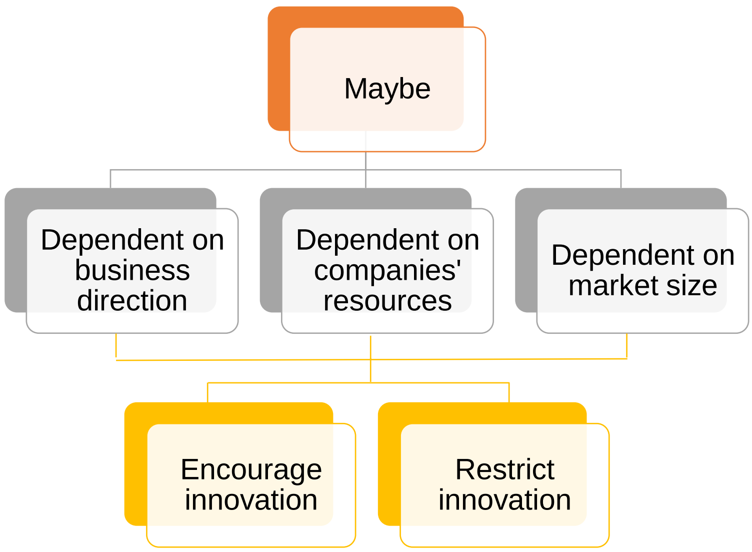
For the first theme, a sub-theme was further identified from the responses. Interviewees who said market demand affected companies' level of innovation, further said that it encouraged innovation.



According to Interviewee E *"market demand encourages innovation within* [companies]*"*. The interviewee further said there were companies, including their own, that was *"constantly looking at the market to see if* [their company were] *able to innovate based on what* [was] *currently in demand"*. There are also *"cutting edge"* (Interviewee E) companies that actively invest and develop new products and technologies based on the demands in the market, in order to stay ahead of the competition.

Interviewee H also said some companies were encouraged to innovate based on market demand as they want to offer *"potential customers with products that offer that extra little bit of performance"*. This was also highlighted by Interviewee B who said *"*[their] *innovations should* [be] *smarter than* [their] *competitors"* as it benefits the company. Manufacturing companies *"need to be innovative in order to stay in the market"* (Interviewee G). According to Interviewee G, companies' competitiveness would be affected if they *"do not jump at the opportunity"* when there is a gap in the market. As such, market demand encourages innovation in manufacturing companies.

For the second theme, three sub-themes were further identified from the responses. The three sub-themes identified are 'dependent on business direction', 'dependent on companies' resources' and 'dependent on market size'. These sub-themes then either 'encourage innovation' or 'restrict innovation' within manufacturing companies.



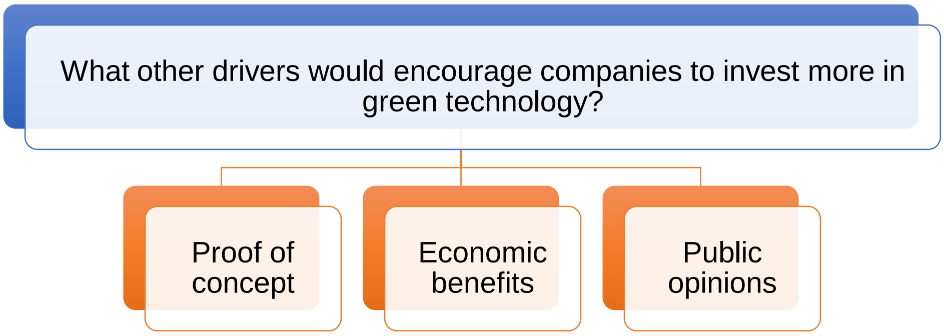
Although market demand is the *"primary force … driving innovation"* (Interviewee C), there are factors that companies need to consider first before it could result in new product innovation. According to Interviewee G, companies *"would not just* *jump into any market gap or opportunities available"*. As such, factors that need to considered first are related to the direction of the company, resources available and market size for the product.

Firstly, companies need to determine if the product in demand fits into their company's portfolio before making any investments. Interviewee G said that companies, including their own, *"would not consider entering the market"* if the product in demand was *"not within* [their] *product range or services"*. The product *"has to be something along the lines of what* [they] *are already doing"* (Interviewee G) before it could result in new product innovation.

Secondly, companies need to consider the availability of their resources. Although some manufacturing companies have *"the finances to chase for innovations as they are not limited to budget"* (Interviewee E), small or private companies may have budget restrictions that affect them from innovating.

Lastly, companies need to consider the market size for the product. Interviewee D said some companies, including their own, were unable to innovate if the market for the product is significant. This is because the company *"would not have the finances or resources to support* [their] *customers in the long run"* (Interviewee D). According to the interviewee, *"significant resources* [are] *required to innovate on a large scale"*. After considering those three factors, market demand may either result in increased innovation within companies or restrict their innovation activities.

Question 6:



Three themes were identified from the responses when interviewees were asked to specify other drivers that would encourage companies to invest more in green technology. The three themes are proof of concept, economic benefits and public opinions.

The first driver identified is 'proof of concept'. According to Interviewee E, if there were proof that particular technology was functioning as programmed, it would encourage other companies to also invest in that technology. The interviewee highlighted that there were currently *"a lot of companies and projects out there* [with] *good plans and ideas, but* [was] *mostly all conceptual"*. If those projects in the conceptual stage were *"developed into something beyond that, such as … being commercialised"* (Interviewee E), other companies would then be encouraged also to get involved.

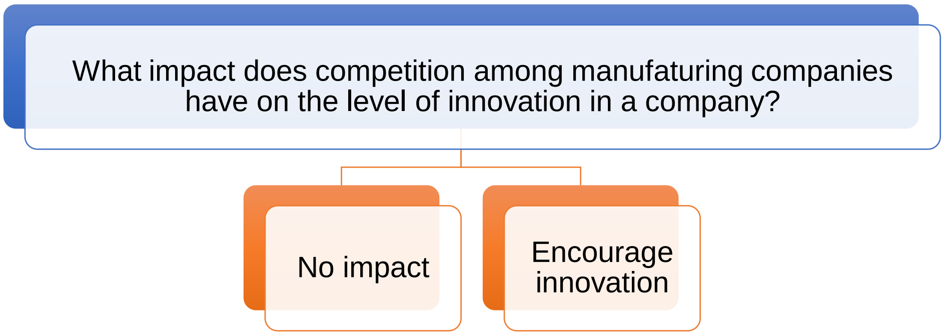
The second driver identified is 'economic benefit'. According to Interviewee A, companies may be driven to invest more in green technology if they realised the economic benefits it would bring to their company. *"Investing in green technology such as wind-based technological solutions, has significant economic benefits to companies"*, said Interviewee A. This is because there is a demand for such products as the *"world is moving towards a very low or zero-emission standard"* (Interviewee A).

Using and producing fuel alternatives such as LNG has *"particularly* [no] *strong advantages"* for the industry to meet the low or zero-emission target, as LNG is *"still a fossil fuel* [with] *significant methane problem",* added Interviewee A. This may contribute to the shipping industry to look for technological solutions to meet the target. Companies would, therefore, be encouraged to invest in wind technology as the economic impact would be significant.

Fluctuations in oil price is another way equipment manufacturing company could realise the economic impact of investing in green technology. According to Interviewee C, rising oil prices have led to ship-owners to reduce their fuel consumption by slowing down their ship's speed. To reduce their dependency on fuel, some ship-owners may be looking at technological solutions to power their ships. Manufacturing companies may, therefore, be driven to invest in green technology based on the potential economic benefits it would bring to the company.

The third and final driver identified is 'public opinion'. Interviewee F said that companies, including their own, may be encouraged to invest more in green technology from public opinions. According to the interviewee, public opinions mattered to their company. If there were a significant issue in the matter from the public, the company would investigate if *"it* [was] *something that* [they] *as a company could offer"* (Interviewee F). Public opinion, therefore, drives the company to invest in green technology.

Question 7:



Responses to the question on the impact competition among manufacturing companies had on the level of innovation in a company, were grouped into two themes. The two themes are ‘no impact’ and ‘encourage innovation’.

Interviewee C personally felt that competition had no impact on innovation activities in a company. The interviewee said that there was *“no real competition”* among companies with regards to innovating products that were similar to one another. The interviewee did, however, said the company that managed to market their product first, would attain the first-mover advantage.

According to Interviewee H, companies innovate based on their capabilities and direction of the company. As such, even if other companies were developing similar products as their company, it did not mean they also had to innovate. The interviewee considered competition among companies to be an advantage. It showed that the company was *“not alone”* (Interviewee H) with their ideas as there were others out there who were also thinking of the same idea. This benefits all companies involved, as their shared interest would enable them to share their findings.

Although competition had no impact on the level of innovation in a company, it does impact their product sales, where the number of products sold may decline. As such, competition impact how companies *“market and value their products”*

(Interviewee E). According to Interviewee E, companies *“need to watch closely on* [their] *price offering”* to be competitive in the market. This may result in constant *“battling on the price of products with other companies”* (Interviewee E) to the point that products may be sold at a minimum profit *“to survive”* (Interviewee D).

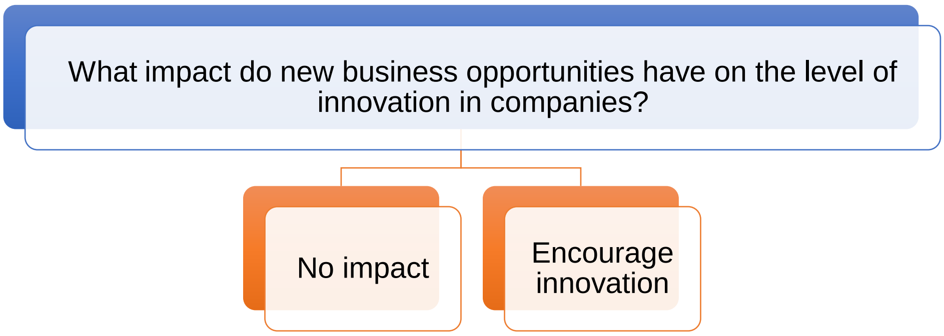
Interviewee E pointed out that companies were unable to offer too low of a price on their product to be competitive as they had to “*take into consideration the amount of time, skills and expenses that* [went] *into manufacturing of such products”*. Companies may have to look for innovative ways to offer their customers with better products at a competitive rate. This may be possible through the availability of *“new technology that reduces overall production costs”* (Interviewee E).

Companies may also focus on their customer service to remain competitive. This strategy was adopted in Interviewee D’s company. According to the interviewee, their company was focused on establishing a *“trust relationship with* [their] *customers when they* [purchase their] *products”*. Customer’s trust is important as it may result in their loyalty towards the company. In other words, customers may still make purchases from the company, despite other companies having a lower asking price for their products. In extreme cases, a company could acquire its competitor’s business to stub out the competition if the product *“is proven to be successful”* (Interviewee A).

On the other hand, some interviewees said competition increases the level of innovation in a company. According to Interviewee B, constant changes in the market may give rise to such competition where companies are encouraged to innovate. It *“drive* [companies] *to be more active”*, said Interviewee A. The reason companies innovate based on competition may be because they want to offer their customers with better products from their competitors to *"remain in the game"* (Interviewee B). This view was also shared by Interviewee G, who further said that companies *"need to be competitive on technology"* pushes them to be innovative.

"Companies could lose potential customers if [they were] *not competitive and constantly upgrading* [their] *products or product offering"*, said Interviewee G. The interviewee further said that competition *"could directly arise from different variations"* of a product. This was based on the interviewee's observation of the market, which saw *"more evolution than revolution"* of a product. This included companies developing smaller scrubber units to cater for smaller ships. Although the technology had been around for decades, "*nothing extremely new would* [be introduced] *in the next couple of years"* (Interviewee G).

<u>Question 8:</u>



Responses to the question on the impact new business opportunities had on the level of innovation in companies, were grouped into two themes. The two themes are 'no impact' and 'encourage innovation'.

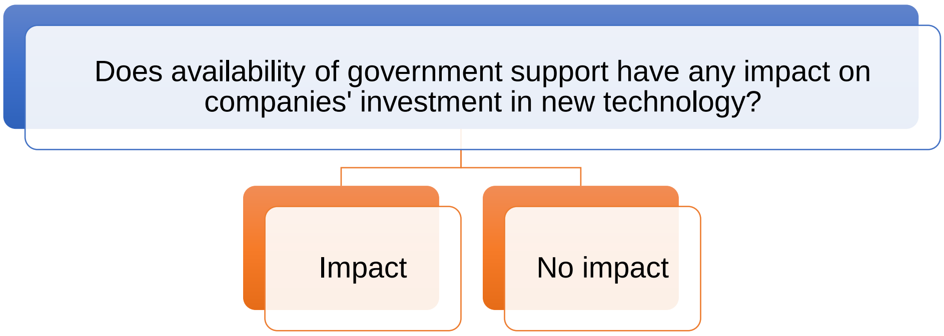
According to interviewee A, the sulphur regulation made ship-owners realised that fundamental change was necessary for their ships. This presented the marine equipment companies with new business opportunities to fill the market with products and solutions for ship-owners to comply with the regulation. However, the interviewee said that this new opportunity had no impact on companies' level of innovation. This is because ship-owners seem uninterested in adopting technological solutions to meet the sulphur regulation unless it is *"really irresistible"* (Interviewee A).

As such, even if there was a new business opportunity, manufacturing companies were not in a rush to innovate because of the lack of interest and demand for technological solutions from ship-owners. Interviewee H said ship-owners would instead opt for distillate fuels than adopt technological products. Furthermore, ship-owners *"must first be convinced that their* [product] *was no longer durable, before they* [could] *change"* (Interviewee C).

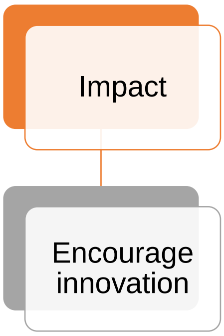
On the other hand, some interviewees said that new business opportunities encouraged manufacturing companies to innovate. According to Interviewee E, such business opportunities may come from manufacturing companies being approached by potential customers with product request. These customers may request for a product with specific specifications that were not currently available anywhere in the market. Manufacturing companies would, therefore, be encouraged to innovate based on the business opportunity presented to them.

However, Interviewee D said that the decision to innovate and enter the market based on new business opportunity was dependent on the management team. According to the interviewee, if the views of the management team leaned more towards *"conservative*", the time taken to evaluate the new business opportunity would be longer and could result in no further actions taken. However, if views of the management team were *"more aggressive"*, these companies would *"go all the way out to capture the market"* (Interviewee D). According to Interviewee D, these companies would innovate so long as they were able to generate new revenues from the products.

Question 9:



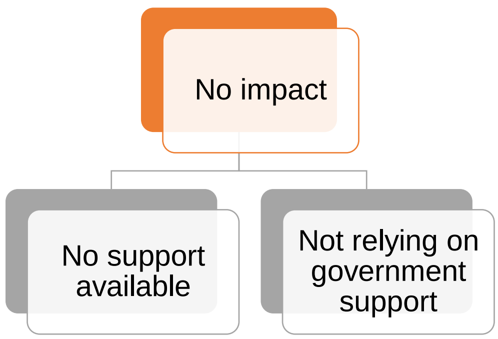
Two themes were identified from the responses when interviewees were asked whether the availability of government support had any impact on companies' investment in new technology. The two themes are impact and no impact.



For the first theme, 'impact', it was found that manufacturing companies were encouraged to innovate based on the availability of government support. According to Interviewee E, *"government support would encourage* [companies] *to innovate more as* [governments] *are providing* [them] *with the funds that* [they] *need"*. This was evident from the interviewee's own company, where they were able to innovate more after receiving an undisclosed amount of grant aid from the government through a scheme that was set up. This encouraged the company to *"constantly applying for funding as and when* [they] *could find it"* to innovate more.

This view was also supported by Interviewee F who said manufacturing companies could *"do a little bit more"* from receiving government support.

However, some interviewees said the availability of government support had no impact on companies' investment in new technology. Two sub-themes were identified from these interviewees' responses: no support available and not relying on government support.



Interviewee A said that there was no government support available to marine equipment companies. As such, government support could not have had any impact on companies' investment in new technology. The interviewee claimed that as shipping is an international business, *"there* [are] *no government support"* available. *"Shipping is just not part of the priority list of things that needs tackling by governments"*, said the interviewee.

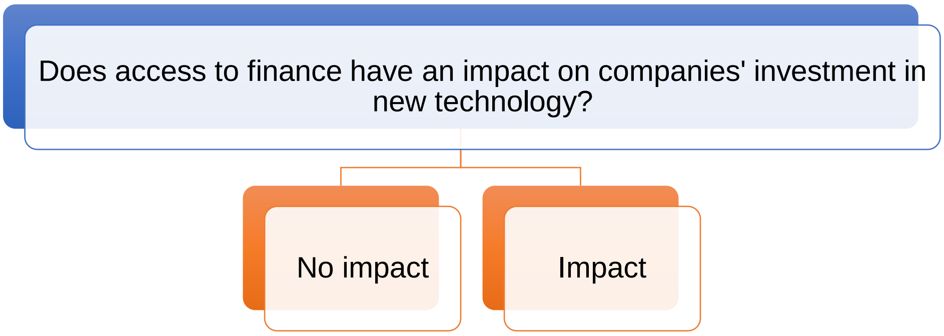
According to Interviewee C, their company had looked *"for every kind of income and help* [they] *could get from governments"* but was also not able to find any form of government support available. Ideally, the company would *"like to have some tax incentives"* made available by governments to encourage them to innovate further. In the meanwhile, the interviewee said their company was relying on public banks and private investors to fund their innovation. The company hope that in the future, governments would provide *"stronger help, support and incentives"* to marine equipment companies.

Even if there were government support available for companies to apply, *"it is enormously expensive to try and get funding"* (Interviewee A). Interviewee E also said the process involved in applying for government funding is challenging. The process takes time and money, and companies are *"always fairly stretched out with* [their] *budgets already"* (Interviewee E). Although the company wants to innovate more, *"there are certain limits of how much time* [they] *have to chase after the funding"* (Interviewee E). Furthermore, companies waiting to receive funding are at risks of losing out to their competitors in the market, as companies with better access to finance would be ahead of them.

Interviewee G also said that the availability of government support had no impact on companies' investment in new technology. This is because there are companies that do not rely on government support to innovate. As such, the availability or lack of government support had no influence on some company's innovation activities. This applied to Interviewee G's company where they innovate to remain competitive irrespective of government support available.

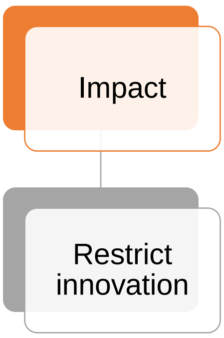
Interviewee D also said government support had no bearings on their company's investment in new technology. The company innovate based on their funds, investments and through collaborative projects with other companies with the same goal. Interviewee D consider government support as *"a form of bribery"* as governments were *"luring the market"* and *"baiting companies"* to innovate by providing support. Although their company was not influenced by government support available, Interviewee D welcomed the efforts made. This is because the support available encourages other companies to invest more in green technology; benefiting the shipping industry.

Question 10:



Based on the responses, two themes were identified when interviewees were asked whether access to finance had an impact on companies' investment in new technology. The two themes are impact and no impact.

The majority of the interviewees said that access to finance does have an impact on companies' investment in new technology. A sub-theme was further identified from the responses: restrict innovation.



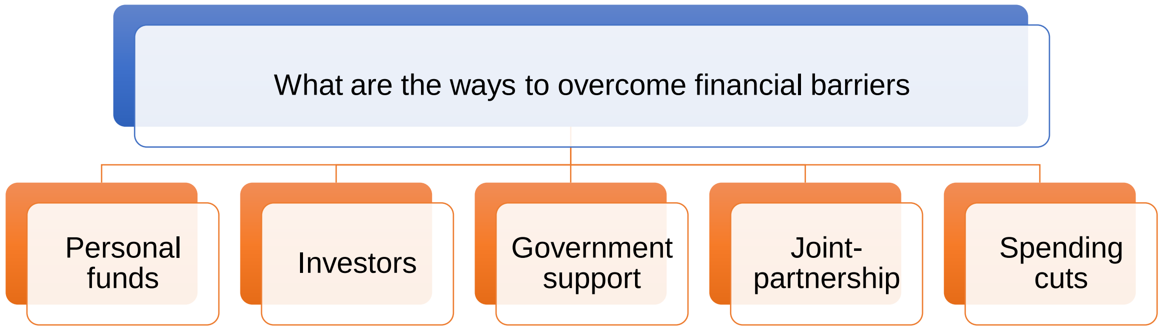
According to interviewee E, access to finance has always been a factor restricting companies' investment in new technology. The interviewee further said that access to finance was even more difficult in situations where there was no active market. In other words, obtaining finance is more challenging for companies when there is no demand for the innovated product in the market. This is because *"investors are unwilling to invest"* (Interviewee H) in such products where they are unable to get a return on their investments. Interviewee C said investors considered new technology as having *“higher risks”,* which also made it challenging for companies to obtain finance.

Interviewee H gave the example of manufacturing companies investing in wind-based technological solutions. Although the market potential for wind-based solutions is significant, there is a lack of demand for such products in the market. As such, those companies may find it more challenging to obtain finance as compared to companies investing in scrubber systems, as market demand for scrubber unit is higher.

Manufacturing companies may also face difficulties in obtaining finance depending on the type and the size of the project. This was highlighted by Interviewee D who said their company were unable to obtain funds required to invest in a large, technologically advanced project. Such projects therefore restrict them from innovating. The company faced no difficulties in obtaining finance for projects that were on a smaller scale. As such, difficulties in obtaining finance restricts manufacturing companies from investing in new technology as they “*do not have money”* (Interviewee A).

On the other hand, Interviewee G said that access to finance had no impact on companies’ investment in new technology. The interviewee set their own company as an example, where access to finance had no impact on their investments. This is because the company is *“not affected by funding”* as they have their *“own funds for development”*. Participating in a fully funded research program also allowed the company to develop new technology.

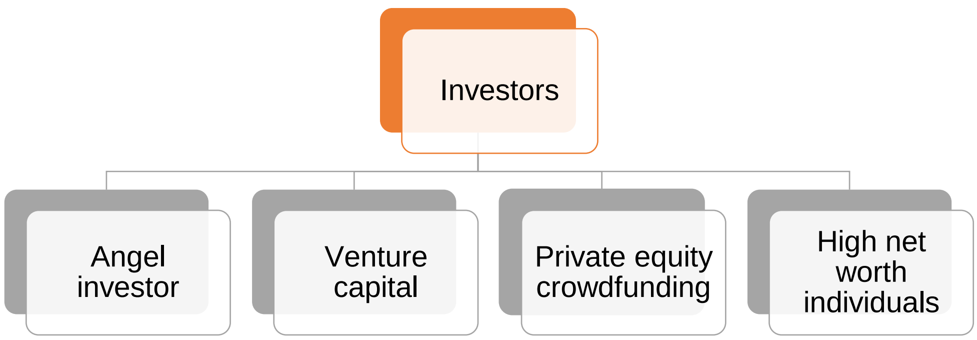
Question 11:



Five main themes were identified from the responses on the ways to overcome financial barriers. The five themes are personal funds, investors, spending cuts, government support and joint-partnership.

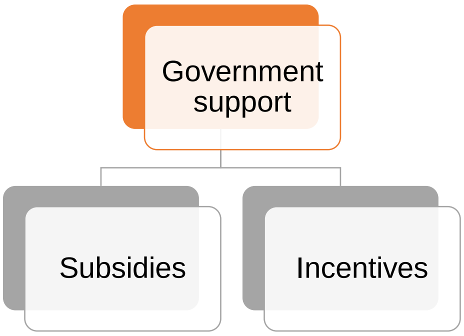
According to Interviewee A, manufacturing companies can overcome financial barriers by having the CEO of the company, or the owner of the company to use their personal funds. However, the interviewee was quick to add that it may only be practical for CEO or owners of SMEs and private companies. This is because using personal funds such as *"pension funds"* (Interviewee A,) is highly unlikely to be enough for larger companies to overcome their financial barriers.

Another way to overcome financial barriers is through investors. Based on the responses, examples of investors identified are angel investor, venture capital, private equity crowdfunding and high net worth individuals.



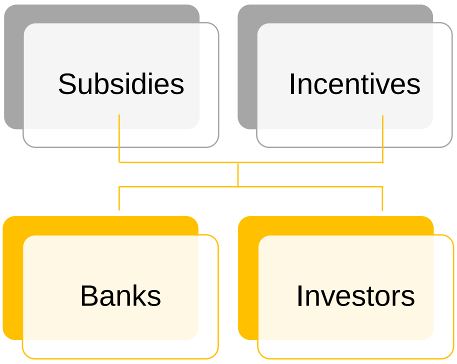
Interviewee H suggested that manufacturing companies should look for "[individuals] *who can see the vision* [of the company] *and are prepared to support* *the management team"*. In order to "[receive] *as much funding as possible"*, Interviewee F said it was crucial for companies to be able to convince or persuade their current and new investors from their *"product pitch"*. According to the interviewee, investors were more likely to invest in a product if they were *"confident that* [the product] *could materialise into something practical"*. Interviewee C said their company has managed to secure *"more than 40 investors"* to fund their innovative projects. Therefore, it is evident that through investors, manufacturing companies can overcome their financial barriers.

Manufacturing companies can also overcome financial barriers by seeking government support. This can be in the form of subsidies or incentives.



According to Interviewee B, there are different government schemes available for manufacturing companies to apply. Regardless of the amount of support received, it would still help companies to overcome their financial barriers. Interviewee C further said that receiving small incentives at the start of the project was as critical as receiving substantial incentives towards the end of the project. This is because companies may not be ready to pitch their ideas to banks or convince investors to invest in their product at the conceptual stage.

The first incentives provide companies with the necessary resources to better conceptualise their ideas before going further. After conceptualising the idea into a workable product, companies would be more confident to pitch their product to investors and banks for further funding. As such, overcome financial barriers may involve a two-step approach by manufacturing companies.

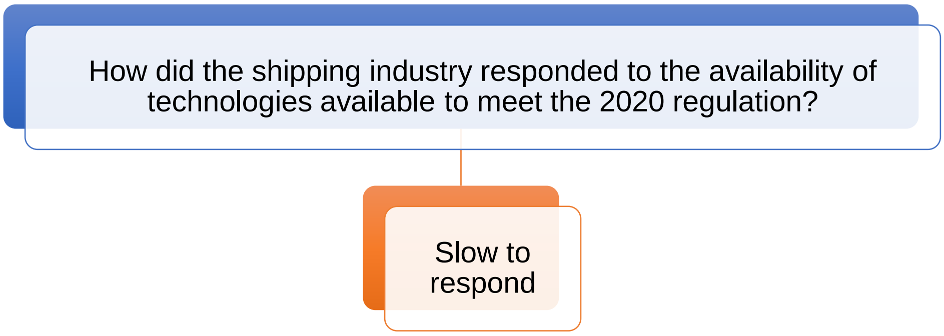


Interviewee F also agreed initial funding was crucial as it had the possibility of bringing more new ideas and products into the market. On the broader perspective, the interviewee believed it was *"probably … the most important thing to do alongside simply setting more ambitious* [emission] *standards"*.

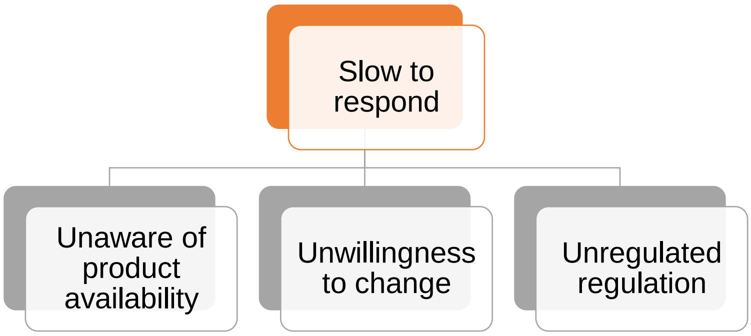
Manufacturing companies could also overcome the financial barrier through joint-partnership. This is where companies *"work* [together] *with* [their] *competitors to become joint partners on some projects"* (Interviewee D). According to Interviewee D, this may involve having one company supplying their highly skilled workforce to another company in return for financial support. Both companies would stand to gain from such collaborative projects, where they were able to *"combine their strength … to achieve the same goal"* (Interviewee D).

Lastly, Interviewee E suggested that companies could consider spending cuts as a mean of overcoming their financial barrier. According to the interviewee, money saved from the spending cuts could then be used *"to reinvest in new projects"*. Money generated from the sales of the products could then be reinvested in other projects. This 'cycle' allows the company to continuously innovate; thereby eliminating financial issues.

Question 12:



All interviewees said the industry was slow to respond to the availability of technologies available to meet the 2020 regulation, *"especially scrubbers"* (Interviewee G). Based on the responses, three sub-themes were identified on the reasons ship-owners responded slowly to available technologies. The three sub-themes are 'unaware of product availability', 'unwillingness to change' and 'unregulated regulation'.



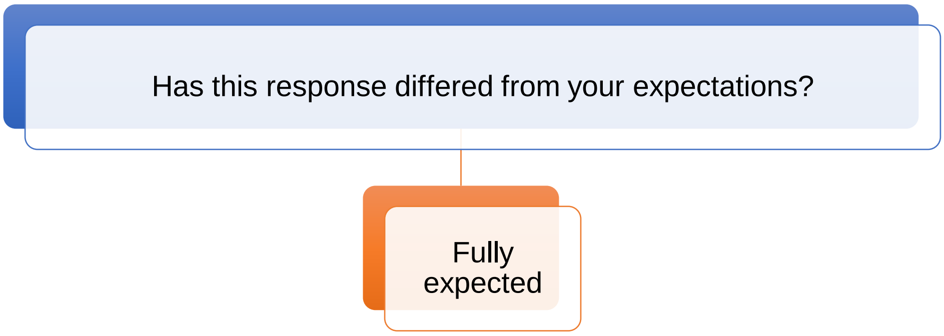
One of the reasons the shipping industry was slow to respond may be because ship-owners were unaware of product availability in the market. Interviewee A said that technological innovations, especially scrubber units, came mostly from companies that were *"outside of the established* [shipping] *network".* Furthermore, some of these companies, especially small innovators, rarely has enough resources to take on the immense marketing for their products. These factors may have somehow, contributed to *"the lack of scrubbers being installed in the industry*", as ship-owners were unaware of its availability (Interviewee A).

Another reason the shipping industry was slow to respond was because of ship-owners' unwillingness to change. Interviewee C said that *"historically and genetically"*, ship-owners were always careful when big investments were involved. Some ship-owners would not even consider adopting new technology for their fleet if the current equipment onboard were still good for another five to 10 years. As investing in new products reduces profits, ship-owners avoid investing in new products to have *"better income at the end of the year"* (Interviewee C). Interviewee C said that *"it is not a question of morality"*, but on the stakes involved.

Interviewee H also acknowledged that ship-owners were bound to their traditional or *"old ways of doing things"* and that change is difficult for them. As this contributed to their slow responses to changes in the industry, the interviewee believed that the uptake of new technologies would be faster if companies' management team consisted of younger generations. This is because the younger generations are not caught up with the traditional ways of doing things.

'Unregulated regulation' is another factor contributing to the slow response from the shipping industry. According to interviewee A, there are ship-owners in the industry who *"do not believe* [the sulphur regulation] *is going to be policed"*. The interviewee said there was still *"an ambivalent amongst some parts of the shipping community"* in the way forward, with some ship-owners thinking that *"they are beyond the law"*. As such, these ship-owners were not taking any necessary measures to comply with the sulphur regulation. This contributed to the slow response from the shipping industry on the technologies available for the regulation.

Question 13:



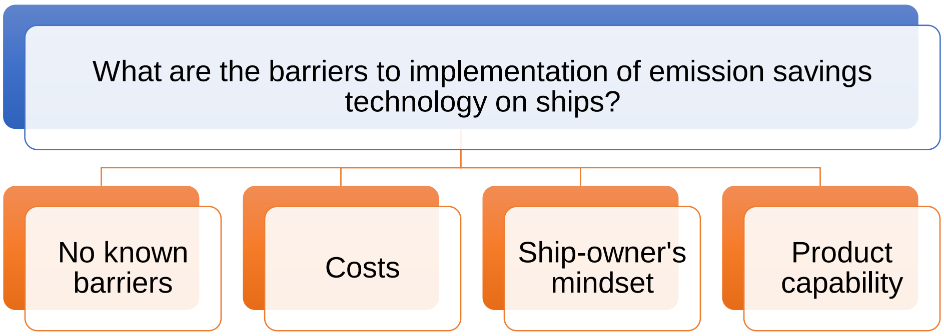
All interviewees said they had fully expected a slow response from the shipping industry to the availability of technologies available to meet the global sulphur regulation.

According to Interviewee A, a slow response was expected from the shipping industry due to ship-owner's mentality that *"climate change is not real"* and that *"it is not happening"*. As such, ship-owners saw no reasons to implement measures which resulted in the slow response to available technologies. Interviewee A further said that change is happening, and it is taking place at a fast rate. The shipping industry need to be prepared for the changes, as any delays could cost the industry even more to implement.

Interviewee C believed there are ship-owners in the industry who are *"innovative as a person"* and fully support the different technologies available to meet the regulation. However, their companies as a whole were *"not convinced"*, nor were they ready to make that kind of shift to adopt new technological products for their ships. These companies viewed the changes as *"simply too much for their own business".*

Interviewee C had a first-hand experienced being in that situation, where a CEO of an undisclosed company was supportive and were keen on adopting technological products on their ships. However, it was not approved by the management committee. Overall, that contributed to the slow uptake of technological solutions.

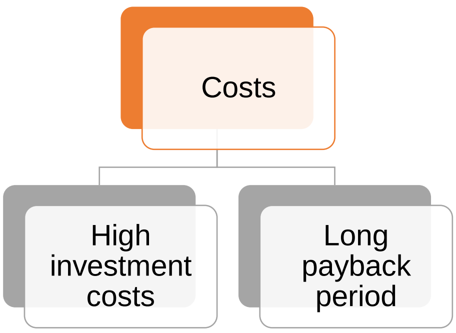
<u>Question 14:</u>



Responses to this question was grouped into four main themes: no known barriers, costs, ship-owner's mindset and product capability.

Both Interviewee G and Interviewee H said there were no barriers. Interviewee G further said technological products such as scrubber systems have no barriers, as both current ships and new builds *"can easily be fitted"* with scrubber unit. Furthermore, Interviewee C said the rise in the number of ship-owners adopting emission savings technology is an indication that there are no barriers to its implementation.

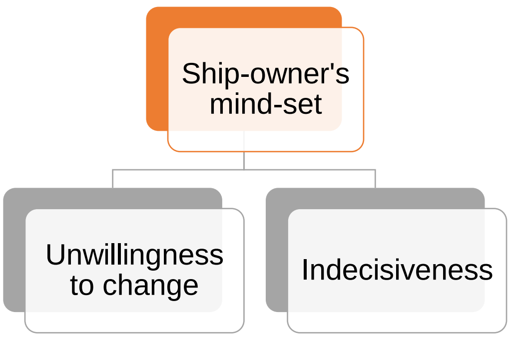
On the other hand, 'costs' was identified as one of the barriers to implementation. Responses under this central theme (costs) were grouped further into two sub-themes: high investment costs and long payback period.



According to Interviewee D, high investment costs contributed to the low number of emission savings technology implemented on ships because ship-owners *"want the cheapest option"* for their ships. Furthermore, the time took *"to earn* [investment costs] *back"* (Interviewee B) for technological products, also acts as a barrier to its implementation. The higher the costs of initial investment, the longer the payback period will be.

According to Interviewee B, some manufacturing companies do provide ship-owners with an estimated payback period of the investment. In the case of a wind-assisted technological product, the payback period is calculated based on the predicted fuel and emission savings. However, the interviewee said payback calculations for scrubber technology is *"far more complicated"* as the estimate is *"strongly dependent on future prices of HFO with sulphur and low sulphur, MGO, LNG, hydrogen and so on, which* [were] *far from clear"*.

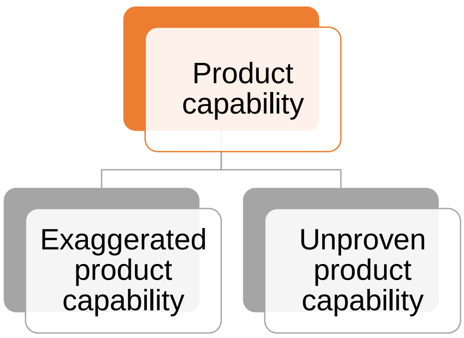
Another barrier to implementation identified is 'ship-owner's mindset'. Responses under this parent theme were grouped further into two sub-themes: unwillingness to change and indecisiveness.



According to Interviewee E, some ship-owners have an *"innately conservative thinking"* where they are *"too focus on maximising profits"* and are unwilling to *"spend money on technology"*. This way of thinking makes these ship-owners *"irresponsible"*. The interviewee further said that some ship-owners would also *“not be too bothered about meeting the* [sulphur] *regulation”* if the risk or penalty for non-compliance is low. Such mindsets and unwillingness to change contributes to the lack of emission savings technology implemented on ships.

There is also the case of ship-owners being *“frightened”* and *“not* [knowing] *what to do”* (Interviewee A). According to Interviewee A, being fearful indicates *“willingness to change”* from ship-owners, but there is *“no clear pathway”* or certainty on how to do it. Complicating matters further for ship-owners are the variety of possible solutions and measures available for them to implement. As such, ship-owner’s indecisiveness also acts as a barrier to the implementation of emission savings technology on ships.

The final barrier to implementation identified is ‘product capability’. Responses under this parent theme were grouped further into two sub-themes: exaggerated product capability and unproven product capability.

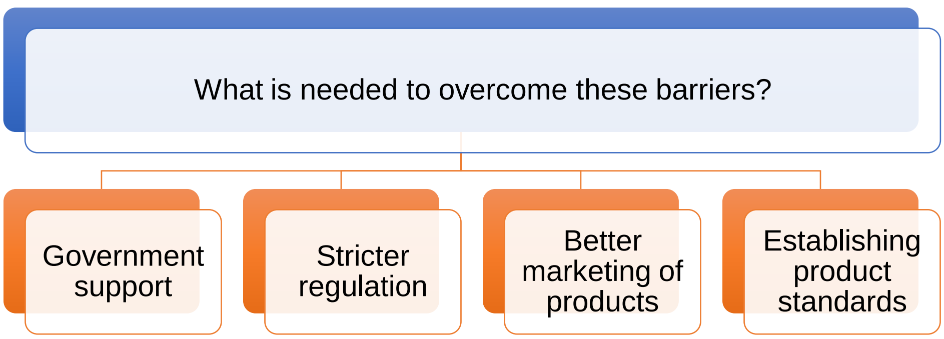


‘Exaggerated product information’, concerning product’s potential savings, was identified as another barrier to implementation of emission savings technology on ships. According to interview F, some manufacturing companies are *“very* [ambitious] *with the assumption”* of their product’s emission savings by claiming a *“very high percentage”* of savings. This ambitious assumption contributed to ship-owners having doubts about the actual savings potential of the product.

As such, ship-owner would need to *"dig deep into those numbers"* (Interviewee F) to uncover the actual savings value, before they could then make comparisons with other products. However, ship-owners could *"grossly underestimate or overestimate the savings"* (Interviewee F) as they may interpret the savings differently. As ship-owners' investment decision is made based on the product's savings, unreliable product information affects the implementation of emission savings technology on ships.

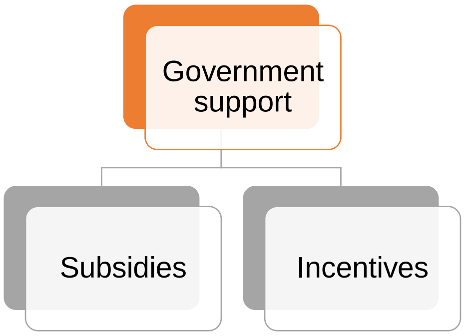
'Unproven product capability' was also identified as a barrier. Interviewee A said there were two separate incidents where technological products installed by ship-owners, "[had] *not lived up to expectations"*. The products involved were scrubber systems and Skysails, each costing the individual ship-owners millions of pounds. As ship-owners wants what is best for their ships, they would not *"invest in a product* [that] *is not proven and reliable"* (Interviewee D). As such, unproven product capability is a barrier to the implementation of emission savings technology on ships.

<u>Question 15:</u>



Responses to this question was grouped into four main themes: government support, stricter regulation, better marketing of products and establishing product standards.

According to Interviewee A, ship-owners *"*[could] *do with more government support"* to encourage them to implement emission savings technology on ships. Such support could come in the form of subsidies and incentives.



Interviewee B said governments could *"*[subsidise] *additional investment costs"* associated with implementing technological products onboard. Such measures reduce ship-owner's investment risks and therefore, have the potential to encourage more ship-owners to adopt technological solutions to comply with the sulphur regulation. Governments could also offer ship-owners with *"extra incentives for emission-free sailing"* (Interviewee H). Example includes financial incentives given to ship-owners, which may encourage more emission savings technology being implemented on ships.

Other than government support, Interviewee F suggested a stricter sulphur emission regulation may contribute to an increase in the uptake of emission savings technology. This is because the interviewee believes the most effective way ship-owners are able to meet a more stringent regulation, is through technological products.

Interviewee C, on the other hand, highlights the importance of product marketing by manufacturing companies to encourage more ship-owners to implement emission savings technology onboard. According to the interviewee, manufacturing companies need to market their products better so that ship-owners are aware of the products available to comply with the regulation. Better marketing of products may be achieved through a *“dedicated branding and marketing strategy”*.

Lastly, Interviewee F suggested a joint industry project needs to be establish. This is where manufacturing companies are able to *“set down industry standards and sets of recommendations on how they should quantify the savings”* for their products. These standards would reassure ship-owners that the products comply with the low sulphur regulation. As such, ship-owners may be more encouraged to implement emission savings technology on ships.

8.4 Summary

This completes the analysis of data for stage two concerning the variables that encourage or restrict product innovation, finance as a factor affecting innovation and barriers to implementation of emission savings technology on ships. The next chapter covers the discussion of this research based on results from the preceding two chapters.

CHAPTER 9 DISCUSSIONS

9.1 Introduction

This chapter presents the findings of this research, which is presented in a narrative format. It starts by revisiting the regulation from which this research is based on, before highlighting the measures (using alternative fuels or adopting technological products) available to ship-owners to meet the regulation. Variables that encourage or restrict innovation are then discussed. As access to finance was identified in **Chapter 2** as one of the key barriers of product innovation (Pinget *et al.*, 2015; Ghisetti *et al.*, 2017; Gupta and Barua, 2018), measures marine equipment manufacturers can implement to overcome financial barriers is identified.

Then, the level of preparedness of the shipping industry in meeting the 2020 regulation, based on the adoption rate of technological products, is examined. These findings are then applied to the regulatory bodies of the IMO and the EU, before making recommendations to further enable cleaner air emissions from shipping. A summary of this chapter is then presented.

9.2 MARPOL Annex VI

The IMO is constantly making amendments to its MARPOL Convention over the years to keep pace with the rapidly evolving technology faced in the shipping world. Recent technological improvements and implementation experience has resulted in the IMO revising MARPOL Annex VI through significant strengthening of the emission limits.

In the revisions, the global emission limit set for SOx is to be reduced to 0.5 percent by 1 January 2020. Depending on the outcome of the fuel availability study commissioned by the IMO, this implementation date could be deferred by five years to 1 January 2025. The study was completed in July 2016 by *CE Delft* and was presented at the 70th session of MEPC. It concluded that there is enough compliant fuel to meet the demand from the global shipping industry. This has led to confirmation by the IMO that the Organisation is moving forward with the 2020 implementation date as scheduled.

However, ship-owners felt that they should had also been consulted and represented in the study. From their involvement in the study, they would have had the opportunity to voice their concerns and had their opinions heard. This may have resulted in a different outcome of the study, where the IMO defers the implementation date by five years. The results from the questionnaire indicated that this was the preferred option by ship-owners to have the implementation date set for 1 January 2025. As such, ship-owners felt that the IMO should have commissioned a more inclusive review. This is because ship-owners are the ones most affected by the decision made at the IMO on the outcome of the study.

Although ship-owners would have preferred to be involved in the study, they felt that enough efforts were made by the IMO to consult industry players before it was decided by the Organisation to implement the regulation in 2020 instead of 2025. Efforts made by the IMO included several talks which had been organised to the benefit of ship-owners where they were able to participate in the discussions. Furthermore, ship-owners had the opportunity to bring up issues they had regarding the implementation date with their respective associations and flag states before the decision was made by the IMO.

However, some ship-owners still felt that the IMO could have organised more discussions and conferences with industry players regarding a viable long-term planning of how the industry could comply with the stringent regulation. This may contribute to the effective implementation of the regulation and avoid issues of non-compliances from ship-owners.

SECA SOx limits and EU Sulphur directives

The 2020 global sulphur limit was not the first regulation of its kind where the shipping industry had to reduce its sulphur emissions. More stringent sulphur limit of 0.1 percent has been in place since 1 January 2015 in emission control areas under Regulation 14.4 of Annex VI and under EU Sulphur Directives. The EU further applied the 0.1 percent sulphur cap limit to ships that are at berth or anchorage within EU ports. As such, the shipping industry has been faced with the task of reducing its sulphur limits since 2008, at a time when the IMO started to progressively reduce sulphur and other harmful emissions from ships.

The results show the majority of ship-owners are affected by the 0.1 percent sulphur limit in SECA and EU ports. This meant that a solution had been adopted by these ship-owners to comply with the 2015 low sulphur regulation. As seen in **Figure 9-1**, the most popular measure adopted by ship-owners to meet the 0.1 percent sulphur cap is by using low sulphur fuel oil; used by an average of 90 percent of ship-owners. In comparison, only an average of 16 percent of ship-owners uses scrubber systems to comply with the 0.1 percent sulphur regulation.

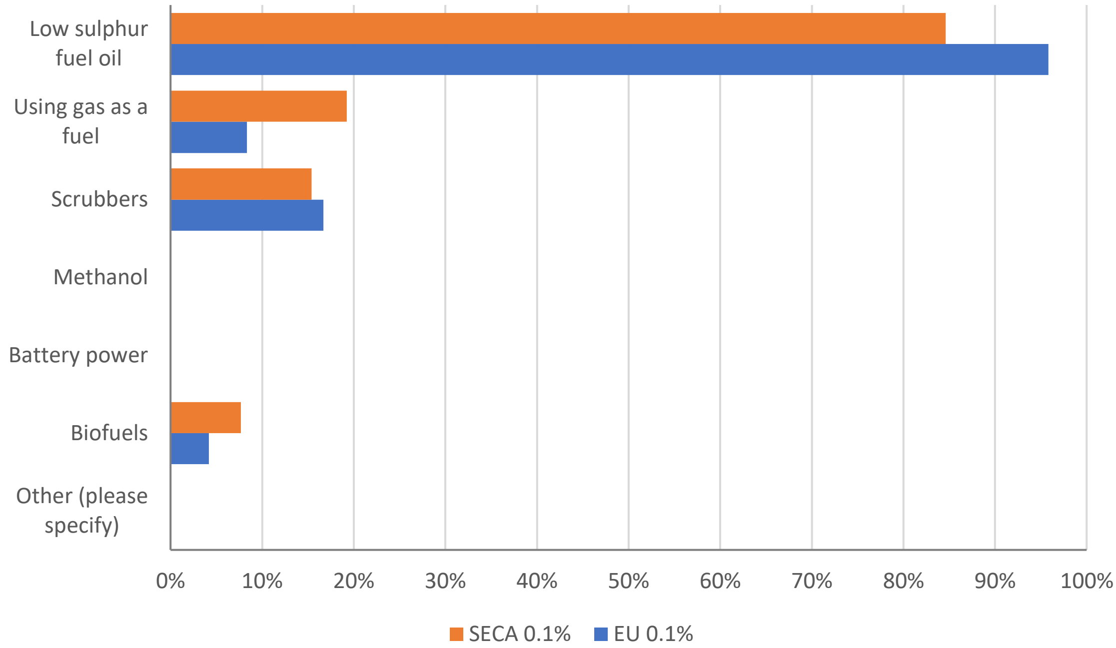


Figure 9-1 Measures to meet 0.1 percent sulphur cap (based on values from Figure 7-2 and 7-3)

As the 0.1 percent sulphur limit is lower than the global 0.5 percent limit, ship-owners can implement the same solution to comply with the 2020 regulation. The results show an average of 74 percent of ship-owners (**Figure 9-2**) would continue using the same solution used to comply with the 0.1 percent sulphur limit, for the global sulphur regulation. This indicates that LSF is the preferred solution to be adopted by ship-owners to comply with the 2020 global sulphur regulation.

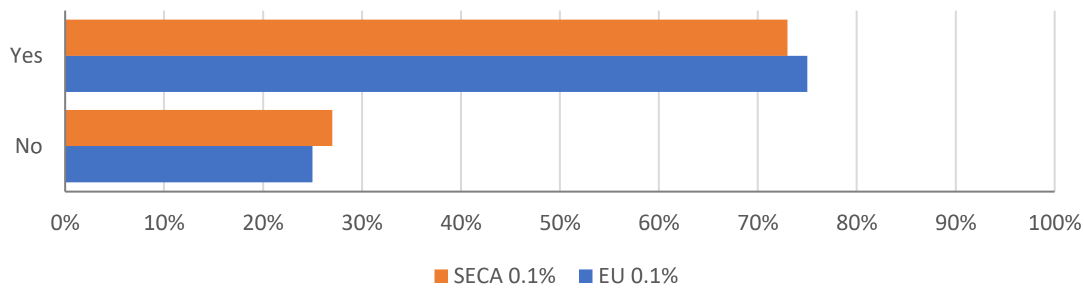


Figure 9-2 Percentage of respondents who would employ the same solution to comply with the 2020 regulation (based on values from Question 5 and 10)

As for the remainder of ship-owners who indicated they would not be employing the same solution, the solution they were referring to was LSF. These ship-owners were considering adopting scrubber systems to comply with the global sulphur regulation rather than using LSF. If the outcome of their cost-benefit analysis for using scrubber proves to be good, the industry may see an increase in the number of scrubber units installed nearing to the 2020 deadline, while the number of ships using LSF will decline.

<u>Potential spread of ECA</u>

Under the revised Annex VI, national governments are encouraged to individually or collectively seek approval from the IMO for the introduction of new ECAs to reduce emissions in designated geographical coastal areas. Establishment of new ECA have major health and environmental benefits for the world as it significantly reduces the amount of harmful emissions from ships. The shipping industry may potentially see a spread in ECA boundary. This may influence ship-owners decision on the solution to adopt for the 2020 sulphur regulation. This is because ship-owners may require the adopted solution to be able to comply with all the regulations faced by their ships.

The results show the spread of ECAs did not affect the majority of ship-owners and it did not have any impact on their decision-making process on selecting a solution to comply with the 2020 sulphur regulation. Those affected said that it was because their fleet were already trading in those areas. As such, the spread of ECA meant these ship-owners were expecting their overall operating expenses to increase. This is due to the more expensive 0.1 percent sulphur fuel price.

Although these ship-owners were worried about the price differential between 0.5 percent fuel and 0.1 percent fuel, one of the respondents said that it may have no impact on ship-owners. This is because under current circumstances, the expected price difference between the two fuels are not significant (Jordan and Hickin, 2017). Furthermore, it is also expected that 0.5 percent sulphur fuel being supplied at a premium rate, will diminish once the initial phase of complying with the 2020 regulation has passed (ABS, 2013). As such, the price of 0.1 and 0.5 percent sulphur fuel should not be a factor influencing ship-owners from using alternative fuel to comply with ECA and global sulphur regulations.

Apart from using alternative fuel, these ship-owners were also considering installing scrubbers so that they could comply with both regulations. However, the need for careful analysis was cited by respondents, as the decision on selecting the best solution for their fleet varies depending on requirement. The price and availability of LSF, in addition to costs involved with retrofitting scrubbers, was highlighted as factors for consideration, on adopting a long-term solution. Based on these analyses, it is evident that there is a demand for technological products to meet the 2020 regulation from ship-owners. The next part of this chapter looks at all the solutions ship-owners are adopting to comply with the regulation.

9.3 Measures to comply with global sulphur regulation

With the impending 2020 sulphur deadline, ship-owners have the option of either using alternative fuel to power their ships or implement abatement technology onboard to comply with the regulation. Alternative fuels ship-owners could switch to include LSF, LNG, methanol and biofuels. As for technological products, ship-owners can retrofit their ships with scrubber systems, adopt wind-assisted propulsion units such as Flettner rotors, or install solar panels. The advantages and disadvantages of all these measures had been covered earlier in **Chapter 4**.

However, the process of selecting a solution is not as straight-forward as it seems, but one that requires thorough planning and deliberation by ship-owners. Some of the factors ship-owners need to take into consideration include: cost and availability of LSF, using other alternative fuels such as LNG, building new eco-ships, environmental impacts of the solutions, and the availability and feasibility of using scrubber technology. This may be the reason ship-owners preferred the implementation date of the sulphur regulation delayed to 1 January 2025, so that they have more time to consider and weigh all viable solutions before selecting one that fits their requirements.

The results found that most ship-owners were not in any rush to implement any changes to their operations in complying with the sulphur regulation. In other words, most ship-owners were continuing their operation in a 'business as usual' scenario, where ships still use fuels that are high in sulphur content, such as heavy fuel oil (HFO). Despite the low sulphur requirement being known in the shipping industry for quite some time, some ship-owners indicated they were 'quite unprepared' to comply with the regulation before the deadline.

Furthermore, almost half of the ship-owners indicated they would wait for an outcome from the industry, instead of taking their own efforts to decide on a solution to comply with the regulation. These ship-owners were willing to wait until end-2018, one year before the regulation comes into force, before deciding on a solution to implement. As most ship-owners thought the sulphur regulation will be enforced 'quite strictly', those who do not comply by the deadline risks being imposed with fines and sanctions for non-compliance.

Although 52 percent of ship-owners that participated in this research has yet to decide on a solution, they felt the shipping industry in general, is able to comply with the sulphur regulation before 1 January 2020. As for the remainder 48 percent of ship-owners who had selected a solution to comply with the sulphur regulation, the most selected solution is LSF (54 percent), followed by scrubber systems (20 percent).

9.3.1 Alternative fuels

The results show the most preferred solution to comply with the 2020 sulphur regulation is by using LSF. Ship-owners who adopt this solution said LSF is the most practical solution as it avoids major investments in older ships for the retrofitting of scrubbers. However, there is still the issue of fuel availability.

A study done by consultants *Ensys* and *Navigistics*, which were not commissioned by the IMO, opposes *CE Delft's* findings that there is enough compliant fuel to meet the demand from the global shipping industry in 2020. The study found that the refining capacity would not be enough to meet global demands in 2020, while maintaining uninterrupted supply of fuel to all other sectors of the global economy.

Despite conflicting results from both studies, the majority of ship-owners indicated that it would not affect their decision in using compliant fuel as a solution to meet the sulphur regulation. Although this is evident that the majority of ship-owners are not worried about uncertainty in the supply of LSF, there are already issues with its supply faced by current ship-owners using the fuel. The issue on the supply of LSF will only exacerbate as the 2020 deadline nears as there may be an influx in the number of ship-owners opting for LSF.

The majority of ship-owners were also to some degree, worried on the price fluctuations of low sulphur fuel. This is brought about by the unpredictability in the supply of the fuel which may potentially cause LSF providers to supply it at a premium rate. This would have an influence on ship-owners decision to use LSF as the price fluctuation may result in LSF to be a more expensive solution to adopt as compared to other solutions such as scrubbers.

9.3.2 Technological measures

Based on all the technological products available to ship-owners to implement to comply with the sulphur regulation, scrubber system is the preferred option. This is because the unit has been retrofitted on more ships than any other technological products, such as Flettner Rotor.

As covered in **Chapter 4**, there are several types of scrubber systems offered in the market for ship-owners to retrofit on their ships. This ranges from the standard wet and dry scrubbers to a more recent innovation: membrane scrubbers. One of the main disadvantages found with regards to adopting scrubber technology is, ships need to be placed on off-hire for a period of time for installation process to be carried out. Ship-owners will not be earning revenues for the period the ship is on off-hire. This affected ship-owners' decision-making process in choosing scrubbers to comply with the sulphur regulation.

Furthermore, ship-owners also need to consider the availability of repair docks or dry-docks for the installation process; especially leading up to the 2020 deadline where there could be a sudden influx of ship-owners wanting to retrofit their ships with scrubber technology. There is some level of concern (**Figure 7-11**) from ship-owners on the availability of repair docks or dry-docks which further affect their decision-making process in choosing scrubbers as their solution for the 2020 regulation.

However, ship-owners that have retrofitted their ships with scrubber technology said that it made more economical sense to adopt the systems on their ships that are new, modern and with a long lifespan ahead. Some of these ship-owners discovered from their feasibility study on adopting scrubbers that it was not practical for them to retrofit the units on ageing ships, as its costs outweigh the age of the ship.

Ship-owners could also consider scrapping their ships early as a solution to comply with the sulphur regulation. However, the results show that only approximately 17 percent of ship-owners are taking this into consideration. The two main factors influencing ship-owners' decision to scrap their ships early was down to ship's age and costs of retrofitting scrubber systems. These two factors are interlinked to one another as it is not justifiable, nor would it be practical for ship-owners to retrofit expensive scrubber systems on ships that is nearing its lifespan. The high costs involved in retrofitting scrubber systems only makes it practical as a long-term investment for ship-owners.

Overall, it is evident that there is a demand for technological products from ship-owners to comply with the sulphur regulation. As such, demand from ship-owners is considered as one of the drivers encouraging equipment manufacturing companies to innovate. The next section looks at market demand as a driver of innovation in more details, along with the other drivers of product innovation identified from the results.

9.4 Drivers of innovation

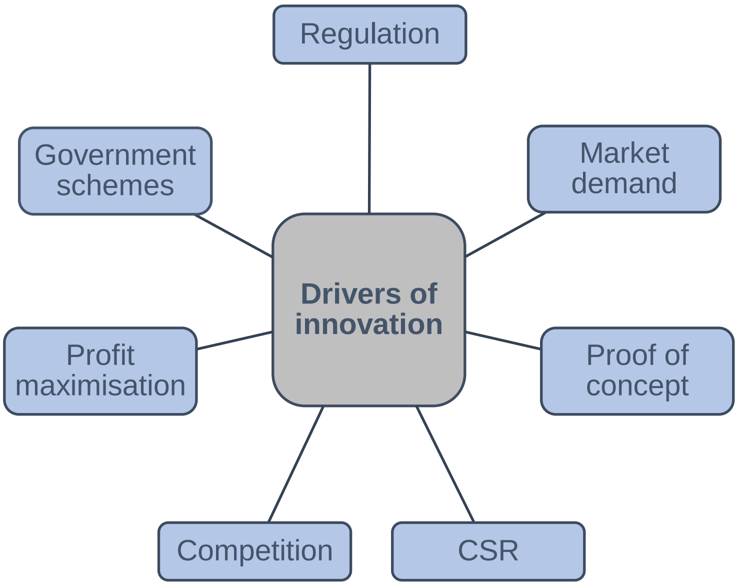


Figure 9-3 Drivers of innovation

Source: Author's own 2019

The drivers of product innovation in the marine equipment sector is shown in **Figure 9-3**. These drivers were identified from the results in this research.

<u>Regulation</u>

The results found that the sulphur regulation is one of the key drivers of green product innovation in manufacturing companies. The sulphur regulation, which is driven by the IMO and supplemented by bodies such as the EU advocating the same message, encourages manufacturing companies to develop products capable of meeting the regulation. It made 'good business sense' for these companies to innovate based on the regulation. The results also found that IMO regulation is the most important factor influencing manufacturing companies to invest in product innovation (**Figure 7-16**).

Market demand

Having a technology or product by itself has no benefits to manufacturing companies if there is no demand for it in the market. The technology or product would be *“sitting on a shelf”* where revenues would not be earned by the company. As such, market demand is one of the key drivers of product innovation identified from the results.

This demand was created from ship-owners’ need for products to comply with the global sulphur regulation. The sulphur regulation has made it necessary for ship-owners to consider their options to comply, which created the demand for technological products in the market. Demand may also be created from ship-owner’s CSR where it calls for their ships to be environmentally friendly. In such situation, these ship-owners would create the demand for ‘green products’ in the market. The results also found that technological products which reduces fuel cost and dependency on carbon fuel were also in demand from ship-owners. Therefore, manufacturing companies are encouraged to innovate based on these demands.

However, it is also important to highlight that although market demand drives innovation, it may not necessarily result in a product being developed. The results found that companies would only innovate after having considered availability of resources, if the product on demand is within their range and the size of the market.

Proof of concept

There are several companies and projects in the industry with good plans and ideas for technological products to reduce emissions. However, as these are all mostly conceptual, profit-driven companies are not able to justify their investments in such projects as it would not bring them any returns. Should these projects and ideas develop into something beyond that, such as being commercialised, other manufacturing companies are more encouraged to get involved and have a share of the market. Prove of concept offers companies with confidence and assurances that the technology would bring profitable returns for them. Therefore, proof of concept encourages manufacturing companies to invest in the technology and develop their own version of the product.

Corporate social responsibility (CSR)

Company's CSR is another driver of innovation identified from the results. Although some companies may not use such *"image-building-buzz-words"* (Interviewee B), it was found that manufacturing companies innovate to tackle environmental issues facing the general population. This includes innovating to reduce harmful gas emissions from ships and reducing ship's fuel consumption and costs.

Although there are manufacturing companies that *"tend to adhere to CSR as an adjacent type of activity rather than it being called to their business"* (Interviewee A), the results found there are companies that primarily innovate because of their CSR. These companies felt responsible for their own future that their CSR encouraged them to innovate as *"it is the right thing to do"* (Interviewee A). This resulted in these companies to actively undertake research and development (R&D) work to realise how they could solve some of the environmental issues faced in the industry, through their innovations.

However, it is also important to highlight that although company's CSR drives innovation, it may not necessarily result in a product being developed. This is because innovation will not occur if the product is not something the company wants to offer or are able to offer.

Competition

The market is a competitive place where demand and supply are constantly changing. Companies need to constantly upgrade their products or product offering to stay ahead of the competition. Otherwise, they may lose potential customers and their competitiveness in the market. As such, competition encourages product innovation in companies.

Companies may innovate to have a product that is superior than their competitors in the market. Competition could also arise from product specification, where companies compete to develop compact-size products. This is an attractive feature for ship-owners as the space saved may potentially be used for revenue-earning cargo area. There is more possibility for "*evolution than revolution"* (Interviewee G) of products. Furthermore, with the availability of new technology capable of reducing overall production costs, competition could also arise from companies wanting to offer their customers with cheaper versions of the product. Therefore, competition encourages manufacturing companies to innovate so that they are able to retain their dominant position in the market and to survive.

Profit maximisation

Profit maximisation is another driver of innovation as the results found that manufacturing companies were innovating to *"make more money"* (Interviewee G); even if it meant entering a new market segment which is different from the market for their core products. By entering a new market segment, companies will attract new customers for their innovated products; consequently, increasing their revenues through its sales. This shows that manufacturing companies are determined to increase their revenues that they are willing to develop a product aimed at a different market.

Ultimately, companies need to have a constant cash flow for their business to be *"sustainable into the future"* (Interviewee A). As such, manufacturing companies achieve this by increasing their sales and widening their product offering through innovation.

Government schemes

Although providing government support to manufacturing companies to encourage innovation is considered as *"a form of bribery"* (Interviewee D), the results found that companies were driven to innovate based on the support available. These companies received funds they required through the schemes, which encouraged them to innovate even further. The availability of government schemes enabled companies *"to do a little bit more"* (Interviewee F) in terms of innovating new products. Subsidies were also given by governments to companies that invests in new clean technology. This encouraged companies to innovate so that they could benefit from it.

Governments were also distributing grants and loans to manufacturing companies to encourage more innovative products. The results also found that some companies were *"constantly applying for funding* … *as and when* [they] *could find it"* (Interviewee E), to enable them to innovate more. As such, it is evident that availability of government support contributes to encouraging manufacturing companies to innovate.

Therefore, these are the drivers of product innovation identified from the data generated. The next section looks at the barriers to innovation.

9.5 Barriers to innovation

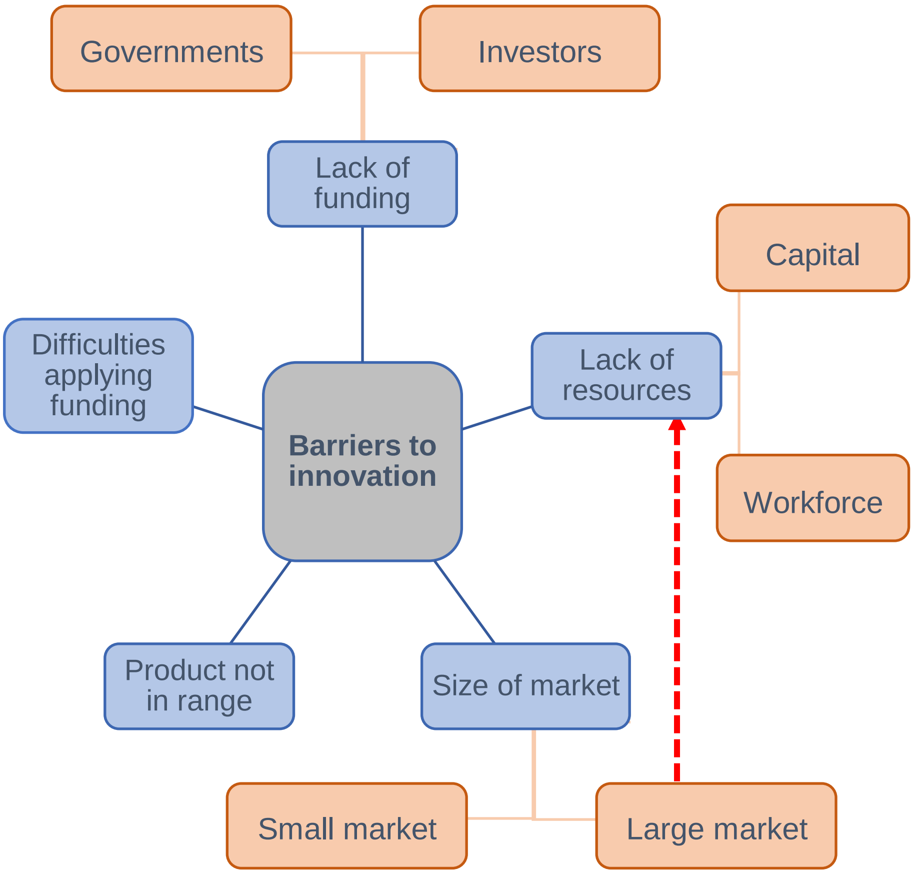


Figure 9-4 Barriers to innovation

Source: Author's own 2019

Apart from drivers of innovation, there are also factors that restricts manufacturing companies from innovating. These barriers to innovation are shown in **Figure 9-4**.

<u>Lack of funding</u>

The lack of funding from governments and investors were found to affect innovation activities in manufacturing companies. Lack of funding poses even greater challenges to companies that were already facing financial constraints from innovating. The results found that investors were unwilling to invest in product innovations that have no active market demand, as they could not see a return on their investments. Investors also considers such product innovations as having higher risks, which further make it challenging for them to invest in the company. This further restricts companies' ability to innovate due to the lack of investors to provide them with the funds required for innovation activities.

Difficulties applying funding

Difficulties faced in applying for funding was found to be another barrier to product innovation. Applying for funding, such as from governments, involves a challenging and expensive process for companies. the time taken for the entire application process is also time consuming. Companies facing financial constraints may not be able to justify investing their time and resources, which were already limited, into applying for the funding. Furthermore, their application might not even be approved; further resulting in greater financial difficulties. This discouraged companies from applying as and as such, impacts their ability to innovate.

Lack of resources

The results found that resources, which include capital and workforce, have always been a factor restricting companies' investment in new technology. Resources constraints were more likely to affect innovation activities in small and private companies as they are more susceptible to having restricted resources and workforce. Their limited resources affect them from being able to innovate freely as compared to larger companies which are not limited to budget. Larger companies were more likely to have their *"own funds for development"* (Interviewee G).

Size of market

The size of the market is another barrier to product innovation. The results found that if the market size for the product is significant and there is greater demand for such products, smaller companies are restricted to innovate. Bigger market size requires greater investments to innovate on a large scale to meet the demand. As such, smaller companies are restricted from investing in a big market due to their restricted finances and resources, which is linked to earlier barrier identified (lack of resources). Furthermore, bigger market also meant that these companies are unable to *"support* [their] *customers in the long run"* (Interviewee D) due to restricted workforce.

On the other hand, companies may also not innovate if market demand for the product is small. This is because the small demand would not cover the significant innovation costs involved in producing the product.

Product not in range

The results found that companies would not develop products that were not within the product range or portfolio of their company. If the product is not *"along the lines of what* [the company] *is already doing"*, companies were unwilling to innovate. As such, the factor is identified as a barrier to product innovation.

Therefore, these are the barriers to product innovation faced by manufacturing companies identified from the data generated. Overcoming these barriers, especially financial barriers, may result in increased innovation activities by manufacturing companies. As innovation activities are capital oriented, it is especially important for manufacturing companies to be able to overcome financial challenges to be able to innovate. The next section looks at ways manufacturing companies can overcome financial barriers.

9.6 Overcoming financial barriers

Based on the results, there are a number of solutions manufacturing companies are able to undertake in order to overcome financial barriers to innovation. These solutions are shown in **Figure 9-5** below.

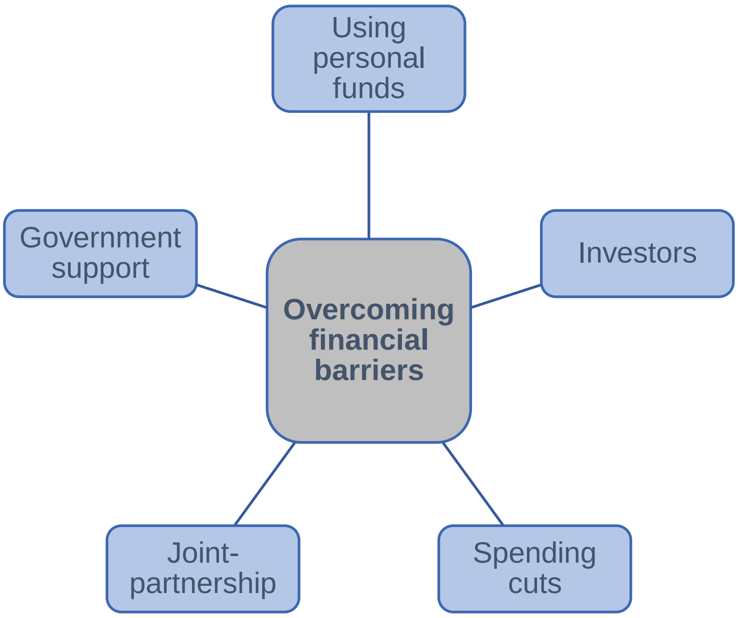


Figure 9-5 Overcoming financial barriers

Source: Author's own 2019

Other ways of overcoming financial barriers includes debt, trade finance, equity, asset finance and cash flow finance.

<u>Using personal funds</u>

One of the identified ways companies can overcome financial barriers to innovation is by using personal funds. However, this is only practical in SMEs or private companies where directors of the company can use personal funds such as their pensions, to fund for company's innovative projects. It is unlikely that financial barriers would be overcome by using personal funds in larger companies.

Investors

Manufacturing companies could also attract investors to help fund their projects. Investors who are *"able to see the vision* [of the company] *and are prepared to support the management team"* (Interviewee A) in their innovative projects helps companies overcome their financial barriers to innovation. It is crucial for companies to be able to persuade their investors so that they can *"get as much funding as possible"* (Interviewee E). Companies' product pitch, therefore, needs to be strong to gain investors' confidence in the product so that they would invest. Investors need to see the potential for earning their investments back.

Spending cuts

Companies are also able to overcome financial barriers through reduced spending. By making financial cuts on certain company's spending, companies can use the money saved to reinvest in new projects. Manufacturing companies are then able to use the money generated from the sales of these new products to further invest in their other projects. This 'cycle' allows the company to continuously innovate; thereby overcoming their financial barriers.

Joint-partnership

Partnership is another way manufacturing company can overcome their financial barriers. Through the partnership, companies are joining forces to work together on a project where one company is providing the resources that the other company lacks. This could involve one company supplying their highly skilled workforce in return for financial support. By combining each company's strength to achieve the same outcome, both companies would stand to benefit. Such collaborative project may help overcome financial barriers faced by companies.

Government support

Manufacturing companies are also able to look towards governments for support, in terms of receiving subsidies or incentives, to overcome financial barriers. Even if the support available is small, it goes a long way in helping companies kick-start their projects. It provides companies with the necessary resources to conceptualise their ideas into something workable, before they have the confidence to pitch their ideas to investors and banks for further funding. In the UK 'Maritime 2050' strategy, the government has set out its ambition to working *"in partnership with the British banking sector to encourage the provision of finance towards zero emission shipping technology development and manufacturing"* (Department for Transport, 2019, p.169). This form of support will further enable manufacturing companies to overcome their financial barriers to innovation; thus, potentially resulting in increased product innovation that can further enable cleaner air emissions from shipping.

9.7 Adoption rate of technology by ship-owners

It is evident from preceding sections that manufacturing companies were faced with various variables that either encourages or restricts them from innovating technological products for ship-owners to comply with the 2020 global sulphur regulation. It is important to realise how the shipping industry responded to the availability of these technological products, where adoption of such products contributes to the effective implementation of IMO regulation.

The results found that the shipping industry was slow to adopt available technology that can meet the sulphur regulation. The reason for the slow adoption was due to factors related to ship-owners' mind-set, costs associated with adopting new technology, and the believe by ship-owners that the regulation is going to be unregulated.

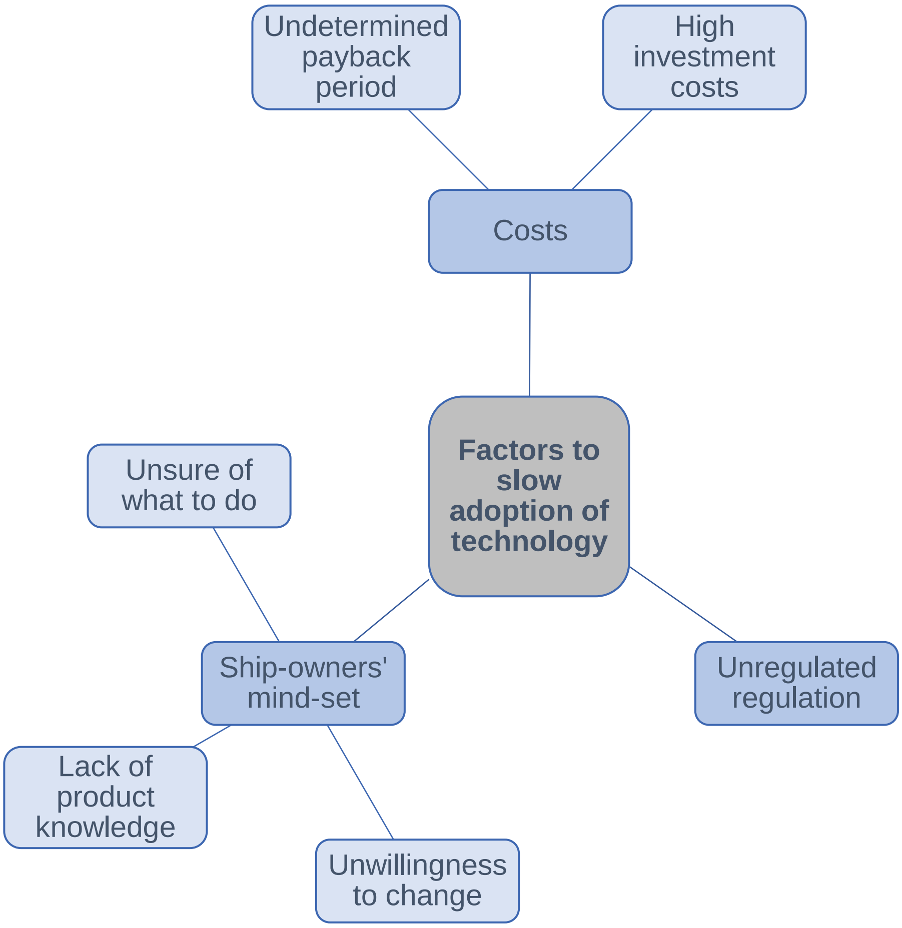


Figure 9-6 Factors contributing to the slow adoption rate of technology

Source: Author's own 2019

"Historically and genetically" (Interviewee C), ship-owners have been known to be always overly cautious when it comes to major changes on their ships; especially when big investments are involved. These ship-owners are bound to their old ways of doing things where they are reluctant to adopt new products, if the current ones being used on their ships are still in good working order.

Installing new products on ships would result in ship-owners' profit to take a dive, as capital are required for investing and purchasing such products. Ship-owners are *"too focused on maximising profits"* that they were unwilling to *"spend money* *on technology"* (Interviewee E). *"It is not a question of morality"* (Interviewee C), but what is at stake. The results also found that the uptake of new technological products would have been faster if the management team are made up of younger professionals who are not bounded to the traditional ways of how the company operates. Furthermore, these young professionals could also be more open and accommodating to changes.

The variety of different technological solutions available for ship-owners to adopt also contributed to the slow adoption rate. Some ship-owners were left unsure of the technological products to adopt that they were willing to wait for an outcome from the industry. Although waiting for an outcome would benefit ship-owners, as they are adopting a product which is proven to work and is reliable based on the industry's experiences, it results in the slow adoption rate of technology overall. The results also found that some ship-owners were willing to wait for new technological products to be introduced in the market, if current technological products do not fit their requirements. Regardless of technological solutions ship-owners decided to implement, they would rather pay more for a proven technology with certainty and quality in the product, than to pay the bare minimum for cheaper, unproven technology **(Figure 7-12)**.

The lack of product knowledge also contributed to the slow adoption rate of technology among ship-owners. This is in relation to the potential emission savings from the technological products. Some manufacturing companies were overly ambitious with the savings that causes ship-owners to have doubts on the actual savings. This led to ship-owners having to compare the savings with other products that further delays the adoption rate of technological products. The amount of emission saved is crucial to ship-owners as it subsequently allows them to calculate the payback period for their investments.

The high costs associated with adopting new technology also contributed to the slow adoption rate as ship-owners do not want to invest more than they supposed to. Furthermore, the results found that ship-owners were unwilling to invest in a product that has an undetermined payback period. Payback period is a crucial information that needs to be made available to ship-owners as their investment decisions are based on that. The longer the payback period is for the product, the higher the costs will be incurred by ship-owners. This may affect their decision in adopting technological products and may result in their decision to opt for compliance fuel instead as it does not involve significant investments.

Ship-owners *"not* [believing the regulation] *is going to be policed"* (Interviewee A), also contributed to the slow adoption rate of technological products. They would *"not be too bothered about meeting the* [sulphur] *regulation"* if the risk or penalty for non-compliance is low (Interviewee E). The results found that some ship-owners had no intentions of complying to the low sulphur regulation; making it unnecessary for them to look at available technological products. These could result in market distortions and creates an uneven playing field for ship-owners that comply with the regulation.

Measures to increase adoption rate of emission savings technology

Based on the results, there are ways which could be implemented in the shipping industry to encourage the adoption of emission savings technology among ship-owners. This includes having more government support, introducing stricter regulation, better marketing of technological products and establishing industry standards.

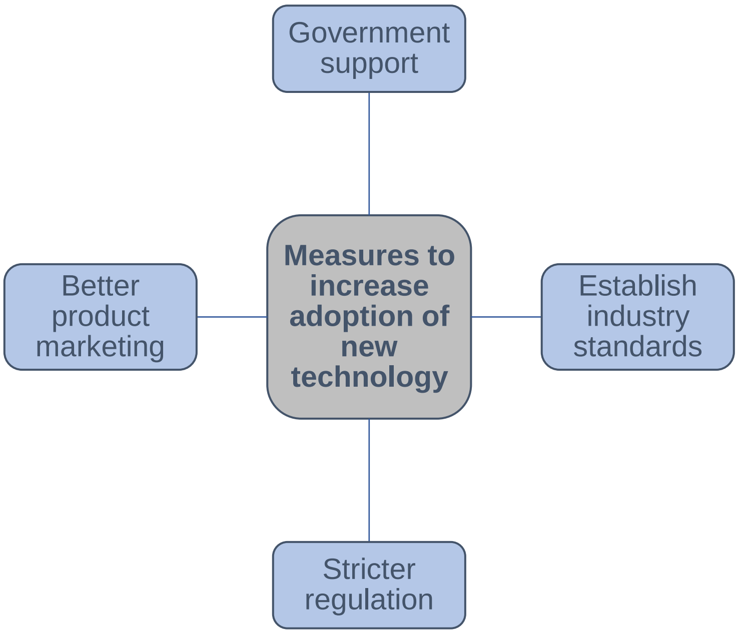


Figure 9-7 Measures to increase adoption of new technology

Source: Author's own 2019

In order to increase the uptake of emission savings technology, governments need to provide more support to ship-owners. This could be through subsidising additional costs to reduce ship-owners' investment risks, or by providing incentives for emission-free sailing. Having an even stricter regulation where emission levels are even lower, could also drive ship-owners to implement technological products on their ships. Similarly, stricter level of enforcement consisting of heavy fines and penalties for non-compliance could also achieve the results.

Furthermore, equipment manufacturers need to better market their products to ensure ship-owners are fully aware of the product details and its benefits. This would avoid unnecessary doubts ship-owners have on the products and gives them more confidence in adopting the technology. In addition, the establishment of a joint industry project on how manufacturing companies should quantify their products' emission savings is also necessary. This information would ensure standardisation of emission savings calculations across the industry. Ship-owners would benefit from this information when they want to invest in a product based on the amount of emission saved.

Based on these finding, it is therefore crucial that equipment manufacturers offer a product that is of high quality and work according to its specifications. This would encourage ship-owners to adopt technological products to comply with the 2020 global sulphur regulation.

9.8 Applying findings to the IMO and EU

Based on the findings, it is evident that there are many variables that encourage product innovation within equipment manufacturing companies. One of the key drivers of innovation identified is regulations. Although regulations are critical to achieve the goal of reduced emissions, Interviewee C said that it is *“very slow and unhelpful”* in managing the issue at hand. In other words, policy makers need to do more than just simply enacting and enforcing more ambitious emission standards, as that alone will not achieve the desired results.

Prior to setting stricter regulations, Interviewee C highlights the importance for policy makers to work closely with other relevant actors, such as industry experts and more importantly, the marine equipment sector. Being in discussions with these actors is of benefit to policy makers, as it enables them to realise if the shipping industry is able to fully comply with the proposed regulation based on current technology available.

Should the technology to meet the proposed regulation does not exist, or is yet to be fully developed, policy makers can delay implementing the regulation. This will enable the marine equipment manufacturers to conduct research and development in innovating a product that is commercially viable to comply to the regulation. However, manufacturing companies may be facing certain barriers that prevents them from innovating (covered earlier in **Chapter 9.5**). These barriers, such as lack of resources and funding, can potentially cause further setback in the effective implementation of the regulation.

To overcome this issue, policy makers can encourage innovation through the use of incentives such as environmental grants (Doran and Ryan, 2012). These grants can be used to fund and support companies' research and development projects as innovation is a capital-intensive process. It may encourage more manufacturing companies, especially small and medium-sized enterprises, to create a product that is able to meet the regulation. More manufacturing companies getting involved would mean that policy makers are able to effectively implement the regulation at a much faster rate. Therefore, government support is crucial in encouraging manufacturing companies to innovate. This view was also supported by Horbach (2008), who stresses the importance of government support.

Through these processes, policy makers are able to ensure that the shipping industry can meet the proposed regulation with little to no difficulties based on the availability of new innovative products; hence, achieving the desired outcome of the regulation. As such, it is crucial for the IMO and the EU as regulatory bodies, to involve all actors who are directly or indirectly affected by the introduction of new regulations, so as to further enable cleaner air emissions from shipping.

9.9 Contribution to theory development

This research has achieved contribution to theory development in a number of ways.

First, this research has conclusive evidence showing IMO and EU regulation is a key driver of green product innovation within the EU marine equipment sector. Previous study by Makkonen and Repka (2016) was inconclusive in their results in showing the innovation inducement impacts of environmental regulations on maritime transport. This research has provided evidence that manufacturing companies within the EU, were encouraged to innovate in green emission-reduction technology based on the stricter sulphur regulation of the IMO.

Second, this research has identified other drivers of green product innovation that were not highlighted in the literature review. The drivers are: economic benefit; IMO and EU regulations; proof of concept; competition; profit maximisation and government schemes.

Third, *product not in range* was identified in this research as a barrier to green product innovation within marine equipment manufacturing companies in the EU. This barrier was not identified in the literature review.

Fourth, this research provides a methodological contribution by using a technique that not only facilitate validation of data (through cross verification from two or more sources), but also in developing a comprehensive understanding of phenomena. The research uses both questionnaires and semi-structured interviews as data collection method, whereas previous studies only uses surveys (Gorodnichenko and Schnitzer, 2013; Coad *et al.*, 2014) and secondary data (Zakic *et al.*, 2008).

Last but not least, the overall findings of this research based on the conceptual framework provides a contribution to knowledge. This research has covered the research gap from available literature on the drivers that encourage or restrict innovation in EU marine equipment sector.

9.10 Evaluation of research

Many considerations were considered when designing the research instrument to ensure its validity. In recognising that multiple realities exist, validity of this research was ensured through the assessment of content validity. As such, content validity of this research has been achieved by relying on the literature while constructing the instrument, to ensure that the instrument contains relevant and adequate items to measure the construct: variables that encourage or restrict innovation of green emission-reduction technology in the marine equipment sector. Face validity, which is similar to content validity, is an informal way to check for validity and was achieved in this research through the involvement of this study's supervisors who tested the research instruments.

Validity of this research was further ensured through the assessment of construct validity, which relates to the assessment of suitability of measurement tool to measure the phenomenon being studied. As such, the application of construct validity in this research was effectively facilitated with the involvement of panel of 'experts' who are closely familiar with the measure and the phenomenon. This is evident from the managerial positions of respondents who participated in the research questionnaires and industry experts involved in the interview process.

Validity of this research has also been achieved by having moderators (research director and research supervisor) who ensured responses were genuine and not in any way influenced by 'what we want to hear', thus avoid biasness; participants' accounts were clearly and accurately presented; rich and thick verbatim extracts of participants' accounts were used to support findings; similarities and differences across participants' accounts were identified to ensure different perspectives were represented; and finally, the use of different sources of data collection (a form of triangulation) to compare the results and help produced a more comprehensive set of findings.

As for reliability, it is often demanding and difficult to obtain identical results from qualitative approaches as the data are in narrative form and is subjective. Therefore, instead of obtaining the same results, reliability of this research is assessed by the dependability and consistency of the data. Dependability of the results in this research has been ensured using three techniques: the investigator's position, triangulation and audit trail.

For the first technique, reliability of this research has been achieved by having a clear and transparent description of the research process from initial outline, through the development of the methods and reporting of findings. Therefore, if a study was repeated based on these processes, the findings and results would be consistent and dependable as this research.

For the second techniques, reliability was achieved through the assessment of parallel forms reliability (triangulation). As such, reliability of this research has been achieved by conducting assessment of the same phenomena with the participation of the same sample group via more than one assessment method. This was where the variables that encourage or restrict innovation of green emission-reduction technology in the marine equipment sector was identified using questionnaires and semi-structured interviews. When data from both assessment methods were compared, the results generated was the same. This makes replication of the research to be executed easily.

Finally, with regards to audit trail, the way the data was collected and analysed has been described in detailed. The way in which different themes emerged, and how the results were obtained was also described in detailed. This information could help other researchers to replicate the work and contribute to its reliability.

9.11 Summary

This chapter has presented the results of the research and their claim to validity. Areas of weakness have been acknowledged but in general, the findings are valid for marine equipment manufacturers within the EU.

CHAPTER 10 CONCLUSIONS

10.1 Introduction

This Chapter provides the concluding remarks of this thesis. The layout of this chapter is as follows: Section 10.2 provides a summary of the research, Section 10.3 highlights research contribution to theory development and Section 10.4 provides research implications and suggestions for future research.

10.2 Summary of research

This research started with the intention of discovering the variables that drive green innovation in the marine equipment sector within the European Union, with the aim of applying this knowledge within the European institutional framework for cleaner air. From this, two research questions were formulated:

1. What are the variables that encourage or restrict innovation of green emission-reduction technology in the marine equipment sector?
2. What impact do the institutions of both the EU and IMO have on the innovation of green emission-reduction technology in the EU?

In order to answer the two research questions, the research project was broken down into six objectives, all of which have been realised:

1. To review available literature regarding institutions, innovation, and the current state of the marine equipment sector

In Chapter 2, all the fundamental theories (institutions and innovation) on which this research builds its foundations were examined, and the general variables that encourage or restricts green product innovation were identified. In Chapter 3, the specific institutions used in this research were identified and discussed. Marine equipment sector within the EU was discussed in Chapter 4.

2. To review the literature and identify knowledge gaps between institutional policy and regulation, and innovation in manufacturing

The conceptual framework for this research was formulated based on the summary of the literature review presented in Chapter 5. Research gaps were identified based on this conceptual framework that was used to guide this research.

3. To synthesise current air quality regulation and policy of the EU and the IMO in relation to atmospheric emissions from shipping

A synthesis of the air quality regulation and policy of the EU and the IMO, in relation to atmospheric emissions from shipping, were tabulated in Chapter 3. The understanding of the condition under each regulation allowed for the identification of the measures capable of meeting the regulation.

4. To discover the variables that encourage or restrict innovation

Questionnaires and semi-structured interviews were selected and used to research the variables encouraging or restricting product innovation within equipment manufacturing companies.

5. To analyse the impact of both the EU and IMO, as organisations, on the innovation of green emission-reduction technology in the EU

Chapter 9 analysed the link between IMO and EU institutional framework and the level of innovation of green emission-reducing technology in the EU. The link was drawn from the drivers of innovation identified in Chapter 8.

6. To make recommendations that will further enable cleaner air emissions from shipping

Data generated from the questionnaires and semi-structured interviews were applied to the context of EU and IMO institutional framework in Chapter 9. The recommendations were also addressed in Chapter 9.

10.3 Summary of research findings

Research question 1

The data identified various drivers of green emission-reduction technology in the marine equipment sector. These drivers were: economic benefit; market demand; regulations; proof of concept; CSR; competition; increase revenue and government schemes. Out of these drivers, only market demand was similar to the drivers identified in the literature review; making the other drivers a contribution to knowledge in the context of this research. However, 'technology push', which was identified in the literature review as a driver of green product innovation, was not identified as a driver from the data generated.

Furthermore, it is important to mention that although regulation was identified in the literature review as a driver of green product innovation, its context is not similar to the context of regulation identified from the data generated. In the literature review, the context of 'regulation' referred to the laws and directives regulating manufacturing companies directly. On the other hand, the context of 'regulation' identified from the data referred to IMO and EU sulphur regulation which the shipping industry was governed by; not manufacturing companies.

The data generated has also identified the variables that restrict innovation of green emission-reduction technology in the marine equipment sector. The identified barriers were: lack of government funding; lack of resources (funds and workforce); product not in range and the size of the market. All these barriers, except for 'product not in range', were also identified in the literature review. As 'product not in range' was not identified as a barrier to green product innovation in the literature review, it is considered as a contribution to knowledge.

However, the barriers identified in the literature review related to ‘knowledge’ and ‘technology and resources’, were not found in the data generated. The absence of those factors from the data meant that the marine equipment manufacturers within the EU were not restricted to invest in green emission-reduction technology based on those factors.

Measures to overcome financial barriers, a key barrier to green product innovation, were also identified from the data. These measures were: using personal funds; attracting investors; reduce spending; joint-partnership and seeking government support. These measures of overcoming financial barriers, should they be adopted, can result in an increased level of innovation within companies. Thus, this further drive innovation in green emission-reduction technology in the marine equipment sector within the EU.

Research question 2

Based on the results found in Research Question 1, there are several variables that encourage or restrict product innovation in equipment manufacturing companies. One of the identified variables encouraging product innovation in manufacturing companies is IMO sulphur regulation. As the standards of the sulphur regulation is part of the institutional framework of the IMO, it can be said that institutional framework of the IMO has an impact on the innovation of green emission-reduction technology in the EU. Furthermore, as the EU incorporated IMO sulphur standards into its own regulation, the institutional framework of the EU can also be said to has an impact on the innovation of green emission-reduction technology in the EU.

Although institutional framework of the EU and the IMO encourages product innovation within manufacturing companies, the results found that there were also factors restricting innovation. The barriers include restricted resources (workforce and capital), lack of funding to innovate and lack of demand for technological products in the market which made innovating unattractive for manufacturing companies. To encourage more manufacturing companies to innovate based on institutional framework of the IMO and the EU, both regulatory bodies needs to address those issues and challenges restricting companies to innovate; especially in relation to financial barriers.

Providing manufacturing companies with support to overcome the barriers to innovation may result in the introduction of more technological products in the market. The availability of more technological products in the market for ship-owners to adopt will contribute to the overall effective implementation of the sulphur regulation, as the shipping industry would have more options to select a product that fits their requirements. As such, it is crucial for policymakers to work closely with the marine equipment sector to ensure that manufacturing companies are able to innovate and supply the shipping industry with technological products to comply with the sulphur regulation.

Apart from working together with the marine equipment sector, the results also found that it is crucial for policymakers to have a strong working relationship with the shipping industry. Policymakers needs to have more discussions and consultations with the shipping industry as the results show ship-owners preferred the implementation date of the sulphur regulation delayed to 1 January 2025. Therefore, instead of simply setting stricter regulations, policymakers need to investigate if there are any potential issues that may cause the inability of the shipping industry to comply with the regulation. Addressing potential issues with the shipping industry may result in the effective implementation of the regulation.

Therefore, it is important for policymakers to work closely with the marine equipment sector and the shipping industry to discuss potential issues and barriers to ensure that the regulation achieve its desired outcome of having cleaner air emissions from shipping.

10.4 Research implications and further research

Several implications can be drawn from this research. This knowledge can help other researchers and academics to develop a theoretical framework to engage in further studies.

Firstly, this research contributes to our understanding of the factors encouraging green product innovation and the barriers to innovation within equipment manufacturing companies. The factors identified in this research are specific to marine equipment companies within the EU, that are concerned with product innovation that allows the shipping industry to comply with the 2020 global low sulphur regulation. Future researchers and academics can examine if these factors are also present in other sectors or industries, either within the EU or global. This information will allow other manufacturing companies also to appreciate the benefits, as well as the challenges and risks involved when investing in green product innovation.

Secondly, this research highlights potential measures manufacturing companies are able to adopt to overcome financial barriers. Thirdly, this research emphasises the role of regulatory bodies such as the IMO and the EU, that can play an active role in increasing the development of green product innovations in other pollution prevention areas. Finally, this research provides useful knowledge with regards to the slow adoption rate of new technological products by ship-owners, which may spur more detailed studies in future.

Future studies may also look at all the green product innovations within companies, rather than focusing on a particular individual green product by the company. A deeper understanding of companies' green product portfolio will further enhance our understanding of how and why companies are investing in green product technologies to introduce in the market.

Also, researchers and academics may be interested in investigating the level of enforcement for the 2020 sulphur regulation by port state and flag state. This research may provide insight into whether strict enforcement will result in ship-owners to be more active in finding solutions to meet the sulphur regulation. Thus, resulting in the IMO and the EU to achieve the desired outcome of the regulation.

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APPENDIXES

APPENDIX A Ship-owner's contact list

1	Oesterreichischer Lloyd	Austria	51	Borkum line	Germany
2	CMB NV	Belgium	52	F. Laeisz	Germany
3	Exmar NV	Belgium	53	Eckelmann Group	Germany
4	Fast Lines Belgium NV	Belgium	54	Jacob	Germany
5	Flanders Navigation	Belgium	55	Ernst Russ	Germany
6	INOK NV	Belgium	56	ER Ship	Germany
7	Navigation Martime Bulgare	Bulgaria	57	Freese Shipping	Germany
8	Atlantska Plovidba	Croatia	58	Hanseatic Lloyd	Germany
9	Brodospas Offshore	Croatia	59	Hanse	Germany
10	Iva Shipping Agency Ltd	Croatia	60	Reederei Harmstorf	Germany
11	Rapska Plovidba dd	Croatia	61	Reederei Jüngerhans	Germany
12	Split Ship Management Ltd	Croatia	62	Lubeca	Germany
13	Ahrenkiel Shipmngt (Cyprus)	Cyprus	63	Ahrenkiel Steamship	Germany
14	Ilic Enterprises Ltd	Cyprus	64	Navalis	Germany
15	Intership Navigation Co Ltd	Cyprus	65	Nimmrich & Prahm Reederei	Germany
16	Lemissoler Shipmanagement Ltd	Cyprus	66	Norddeutsche Reederei H. Schuldt	Germany
17	Reederei Nord Group	Cyprus	67	Oldendorff	Germany
18	Uniteam Marine Ltd	Cyprus	68	Poseidon	Germany
19	Alpina Shipping Services	Denmark	69	Orion Reederei	Germany
20	Bjerrum & Jensen ApS	Denmark	70	OPDR	Germany
21	Juhl & Ehrhorn	Denmark	71	PRO LINE Shipping GmbH	Germany
22	WECO	Denmark	72	BD-Shipsnavo GmbH	Germany
23	DFDS AS	Denmark	73	Schoeller Holdings Ltd	Germany
24	Norden AS	Denmark	74	SALAMON	Germany
25	Esvagt	Denmark	75	Rickmers	Germany
26	J. Lauritzen	Denmark	76	Rhenus	Germany
27	J. Poulsen Shipping	Denmark	77	Opielok	Germany
28	Ocean Prawns A/S	Denmark	78	Reederei Warrings	Germany
29	Wind Shipping	Denmark	79	Reederei Thomas Schulte	Germany
30	Uni tankers	Denmark	80	Triton Schiffahrts GmbH	Germany
31	Torm	Denmark	81	Reederei Gerdes	Germany
32	Linda line express	Estonia	82	Rudolf A. Oetker KG	Germany
33	Norfos Shipping Ltd	Estonia	83	Wessels	Germany
34	Amisco AS	Estonia	84	Wyker Dampfschiffs-Reederei	Germany
35	Bore	Finland	85	Vega Reederei	Germany
36	Crystal Pool Ltd	Finland	86	Transocean	Germany
37	Finnlines	Finland	87	TransChart	Germany
38	Godby shipping AB	Finland	88	Sloman Neptun	Germany
39	Tallink	Finland	89	Empros Lines	Greece
40	Transfennica Ltd	Finland	90	Eletson	Greece
41	DYT Yatch transport	France	91	Hellenic Seaways	Greece
42	LouisDreyfus	France	92	Dalex Shipping	Greece
43	CMA CGM	France	93	Chart World	Greece
44	Peter Dohle	Germany	94	Anek Lines	Greece
45	Condock	Germany	95	Aegean Shipping Mngt	Greece
46	Chemikalien Seetransport	Germany	96	Salamis Shipping	Greece
47	Carsten Rehder	Germany	97	Safety Management Overseas	Greece
48	Brise	Germany	98	Pleiades	Greece
49	BBC Chartering	Germany	99	Niovis Shipping	Greece
50	Alianca	Germany	100	Minerva Marine	Greece

101	Iolcos Hellenic Maritime Enterprises	Greece
102	Hellas Marine Services Ltd	Greece
103	Gourdomichalis Maritime	Greece
104	Franco Compania Naviera S.A.	Greece
105	Fairdeal Group	Greece
106	Sirios	Greece
107	ZIM Integrated Shipping Ltd	Greece
108	Tsakos Group	Greece
109	Thenamaris	Greece
110	Tsakos Energy Navigation Ltd.	Greece
111	Target Marine	Greece
112	Attica Group	Greece
113	Sea pioneer	Greece
114	Coeclerici	Italy
115	Costa Cruises	Italy
116	Fratelli Cosulich	Italy
117	d'Amico Group	Italy
118	Elbalink	Italy
119	Grimaldi Group	Italy
120	Marnavi	Italy
121	Ignazio Messina	Italy
122	Premuda	Italy
123	Limarko Group	Lithuania
124	Rederij Doeksen	Netherlands
125	Amasus	Netherlands
126	Anthony Veder	Netherlands
127	W & R Shipping BV	Netherlands
128	Onego	Netherlands
129	Danser	Netherlands
130	Holwerda	Netherlands
131	JR Shipping Group	Netherlands
132	NileDutch	Netherlands
133	Orient Shipping	Netherlands
134	Seatrade	Netherlands
135	Damen Marine Services	Netherlands
136	Spliethoff	Netherlands
137	Stena Line	Netherlands
138	Stolt-Nielsen Limited	Netherlands
139	Seazip	Netherlands
140	WIND	Netherlands
141	Wagenborg	Netherlands
142	Vroon	Netherlands
143	Chipolbrok	Poland
144	Polish Steamship Company	Poland
145	Portline	Portugal
146	Transtejo Soflusa	Portugal
147	OSM	Romania
148	Trasmediterranea	Spain
149	Wallenius Wilhelmsen Logistics	Sweden
150	ACL	Sweden

151	Rederi AB Älvtank	Sweden
152	Concordia Maritime	Sweden
153	Donsötank	Sweden
154	Furetank	Sweden
155	Lars Jonsson Trading AB	Sweden
156	Svenska Orient Linien	Sweden
157	Stena Bulk	Sweden
158	Erik Thun Group	Sweden
159	Wilhelmsen	UK
160	Bibby Line Limited	UK
161	Eletson	UK
162	Condor Ferries	UK
163	Grearbulk	UK
164	Gillie & Blair Ltd	UK
165	James Fisher	UK
166	"K" Line (Europe)	UK
167	London Ship Managers	UK
168	Northlink Ferries	UK
169	Petredec	UK
170	P&O Ferries	UK
171	Scotline	UK
172	Atlantic Marine	UK

APPENDIX B Equipment manufacturer's contact list

1	Andritz	Austria
2	Man Diesel	Denmark
3	PureteQ	Denmark
4	Estanc	Estonia
5	Langh Tech	Finland
6	Norsepower	Finland
7	Wartsila	Finland
8	Crain Technologies	France
9	Neoline	France
10	Propelwind	France
11	Bilfinger	Germany
12	Fuji Electric-Europe	Germany
13	Saacke Marine Systems	Germany
14	Timbercoast	Germany
15	Ecospray	Italy
16	AEC Maritime	Netherlands
17	Alfa Laval	Netherlands
18	Damen	Netherlands
19	Clean Marine	Norway
20	Lade AS	Norway
21	Yara Marine Technologies	Norway
22	Bound4Blue	Spain
23	THiiiNK Holding	Switzerland
24	WindShip Technology	UK

APPENDIX C Cover letter (ship-owner's questionnaire)

Dear Sir/Madam,

Re: Ships to comply with IMO's 2020 global sulphur cap research questionnaire

I am Noor Hasanuddin, a PhD student from Plymouth University (U.K.). I am conducting a study on the promotion of innovation in the marine equipment sector. One of the objectives of my research is to identify the solution that has been, or will be, implemented on ships to meet the global low sulphur regulation of 0.5 percent by 2020.

I seek your kind assistance to participate in a short online questionnaire. The questionnaire should take approximately 10 minutes to complete and it can be accessed from the following link:
https://www.surveymonkey.co.uk/r/low_sulphur_regulations

All responses will remain strictly confidential and anonymous. Data from this research will be stored securely and protected by password access and reported only as a collective combined total.

Through your feedback provided, I hope to better understand the processes involved and the reasons behind the chosen solution implemented on ships. This information will greatly allow me to assess the link between air quality regulation and innovation in the marine equipment sector.

I thank you in advance for participating in this study. Please feel free to disseminate this email to your colleagues or your contacts who can complete this questionnaire.

If you have any questions or concerns regarding the online questionnaire or about participating in this study, you may contact me at
noor.hasanuddin@plymouth.ac.uk

Sincerely,
Noor Hasanuddin (Mr)
PhD student
Plymouth Graduate School of Management

APPENDIX D Cover letter (equipment manufacturer's questionnaire)

Dear Sir/Madam

Re: Measures to meet IMO's 2020 global low sulphur regulation (research questionnaire)

I am Noor Hasanuddin, a PhD student from Plymouth University (U.K.). I am conducting a study on the promotion of innovation in the marine equipment sector. One of the objectives of my research is to identify the variables that either encourage or restrict innovation of green ship technology, specifically in relation to meeting the low global sulphur regulation of 2020.

I seek your kind assistance to participate in a short online questionnaire. The questionnaire should take approximately 10 minutes to complete and it can be accessed from the following link:
https://www.surveymonkey.co.uk/r/marine_equipment_sector

All responses will remain strictly confidential and anonymous. Data from this research will be stored securely and protected by password access and reported only as a collective combined total.

Through your feedback provided, I hope to better understand if institutional climate of both the European Union (EU) and the International Maritime Organisation (IMO) have an impact on innovation in green ship technology. This information will greatly allow me to assess the link between air quality regulation and innovation in the marine equipment sector.

I thank you in advance for participating in this study. Should you not wish to participate in this study, please reply with the subject line 'unsubscribe' to stop receiving future emails.

If you have any questions or concerns regarding the online questionnaire or about participating in this study, you may contact me at
noor.hasanuddin@plymouth.ac.uk

Sincerely,
Noor Hasanuddin (Mr)
PhD student
Plymouth Graduate School of Management

APPENDIX E Cover letter (semi-structured interview)

Dear Sir/Madam

Re: Interview request for PhD research in green technology

I am Noor Hasanuddin, a PhD student from Plymouth University (U.K.). I am conducting a study on the promotion of innovation in the marine equipment sector. One of the objectives of my research is to identify the variables that encourage or restrict innovation of green ship technology, specifically in relation to meeting the low global sulphur regulation of 2020.

I am writing to request an interview with you (either via Skype or at your office) to investigate further on that subject matter. Sample interview questions are as follows:

1. Does regulation from governing bodies such as the International Maritime Organisation encourage manufacturing companies to invest in new technology?
2. Do factors such as access to finance affect companies' investment in new technology?
3. What factors would encourage manufacturing companies to invest more in new technology?

All responses will remain **strictly confidential** and **anonymous**.

If Skype interview is your preferred option, arrangements could be made for the session to take place from January 8, 2018 onwards. If office interview is preferred, it could be arranged from February 1, 2018 onwards. All interview process must end by February 28, 2018.

Thank you for your time and I look forward to hearing from you soon. If you have any questions or concerns regarding your participation in this interview, you may contact me at noor.hasanuddin@plymouth.ac.uk

Sincerely,
Noor Hasanuddin (Mr)
PhD student
Plymouth Graduate School of Management

APPENDIX F Ship-owner's questionnaire

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Thank you once again for taking time off your busy schedule to participate in this research.
The following questionnaire will require approximately *10-15 minutes* to complete.

* 1. Please indicate your position within the company.

- Senior management
- Mid management
- Junior management
- Technical staff
- Other (please specify)

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Sulphur Emission Control Areas (SECAs)

* 2. Are any of your company's fleet trading in the designated SECAs of the Baltic Sea or the North Sea?

- Yes
- No

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Sulphur Emission Control Areas (SECAs)

* 3. In the course of a month, how often does your company's fleet trade in these areas?

- 1-15 times
- 15-30 times
- Mainly trade within the Baltic Sea and/or the North Sea

* 4. How does your company comply with the regulation of having less than 0.1% sulphur content in fuel when trading in these areas? (Please tick all that apply).

- [ ] Low sulphur fuel oil (eg. Marine Gas Oil)
- [ ] Using gas as a fuel
- [ ] Exhaust Gas Cleaning Systems or "scrubbers"
- [ ] Methanol
- [ ] Battery power
- [ ] Biofuels
- [ ] Other (please specify)

* 5. Based on your answer for Question 4, will your company be employing the same solution to comply with the global 0.5% sulphur cap coming into effect on 1 January 2020?

- ( ) Yes
- ( ) No

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Sulphur Emission Control Areas (SECAs)

6. Please briefly explain why your company will not be employing the same solution?

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

EU Directive 1999/32/EC

Ships at berth or anchorage in EU ports must use fuel containing maximum 0.1% sulphur.

* 7. Is your company affected by the above-mentioned requirements?

- ( ) Yes
- ( ) No

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

EU Directive 1999/32/EC

* 8. How often does your company's fleet use EU ports in the course of a month?

◯ 1-15 times

◯ 15-30 times

◯ Mainly uses EU ports

* 9. For those vessels in your fleet that use EU ports, how does your company comply with the regulation of having less than 0.1% sulphur content in fuel? (Please tick all that apply).

☐ Low sulphur fuel oil (eg. Marine Gas Oil)

☐ Using gas as a fuel

☐ Exhaust Gas Cleaning Systems or "scrubbers"

☐ Methanol

☐ Battery power

☐ Biofuels

☐ Other (please specify)

* 10. Based on your answer for Question 9, will your company be employing the same solution to comply with the global 0.5% sulphur cap coming into effect on 1 January 2020?

◯ Yes

◯ No

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

EU Directive 1999/32/EC

11. Please briefly explain why your company will not be employing the same solution?

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Possible future ECA

Areas under consideration includes: Australia, Japan, the Mediterranean and Norway.

* 12. Will your company be affected by the spread of ECAs?

◯ No

◯ Yes
(Please briefly explain why in the comment field below)

* 13. Does this impact your company's decision regarding a solution to comply with the global 0.5% sulphur cap?

◯ No

◯ Yes
(Please briefly explain what is your company's long term solution?)

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Global 0.5% sulphur limit implementation date

* 14. Do you think the IMO have made sufficient efforts to consult with industry players before agreeing to reduce global SOx emissions to 0.5% from 2020?

◯ Yes

◯ No
(Please briefly explain what more the IMO could have done to consult with industry players?)

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Global 0.5% sulphur limit implementation date

* 15. Can you provide an example of how the IMO has reached out to industry players?

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

MARPOL Regulation 14.8: Fuel availability study (completed October 2016)

IMO have made the decision to stick with the 1 January 2020 implementation date after a review on the required fuel oil availability.

* 16. Do you think shipowners should also have been consulted in the review?

- Yes
- No

* 17. Would your company have preferred to have the implementation date put back to 1 January 2025?

- Yes
- No

* 18. IMO indicate that refineries can produce sufficient amounts of compliant fuel oils. However, a supplementary study by EnSys indicate potential problems for refineries to meet the demands. Does this affect your company's decision-making process in using low sulphur fuel as a solution to meet the 2020 deadline?

- Yes
- No

* 19. Is your company worried about price fluctuations of low sulphur fuel?

Not worried (1)	Not quite worried (2)	Somewhat worried (3)	Quite worried (4)	Worried (5)
○	○	○	○	○

20. Apart from costs and availability of low sulphur fuel, what other factors are your company taking into consideration when deciding on solutions to meet the 2020 regulation?

* 21. How likely do you think the shipping industry as a whole will be able to meet the lower sulphur requirements before 1 January 2020?

Unlikely (1)	Quite unlikely (2)	Neither unlikely nor likely (3)	Quite likely (4)	Very likely (5)
○	○	○	○	○

* 22. How strictly do you think the shipping industry will enforce the low sulphur regulations on 1 January 2020? (Enforcement level from Port, coastal and Flag state authorities).

Strict (1)	Quite strict (2)	Neither strict nor lenient (3)	Quite lenient (4)	Lenient (5)
◯	◯	◯	◯	◯

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Sulphur cap deadline of 1 January 2020

* 23. Will the lower sulphur cap deadline of 1 January 2020 have an impact on your company's operations between now and 2020?

Unaffected (1)	Quite unaffected (2)	Neither unaffected nor affected (3)	Quite affected (4)	Affected (5)
◯	◯	◯	◯	◯

* 24. How prepared is your company to be able to meet the lower sulphur cap deadline of 1 January 2020?

Unprepared (1)	Quite unprepared (2)	Neither unprepared nor prepared (3)	Quite prepared (4)	Prepared (5)
◯	◯	◯	◯	◯

* 25. Based on the deadline of 1 January 2020, your company

◯ is taking its own efforts to be in compliance

◯ will wait and see what the industry selects

* 26. If your company is waiting for an outcome from the industry, how long will you be willing to wait before making a decision?

◯ End of 2017

◯ End of 2018

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Retrofitting scrubbers

* 27. Retrofitting scrubbers onboard requires ships to be in drydock for a period of time, resulting in the ship being off-hire. Does this affect your company's decision-making process in choosing scrubbers?

◯ Affected

◯ Unaffected

* 28. As the 2020 deadline nears, how concerned are you with the availability of repair docks or drydocks for the installation of scrubbers?

Unconcerned (1)	Quite unconcerned (2)	Neither unconcerned nor concerned (3)	Quite concerned (4)	Concerned (5)
◯	◯	◯	◯	◯

* 29. Will your company pay more for a proven technology (certainty and quality) or opt for cheaper, unproven technology?

◯ Pay the bare minimum

◯ Pay more for certainty and quality

30. Is your company considering scrapping ships early as a solution to meeting the lower sulphur regulations?

◯ Yes

◯ No

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Retrofitting scrubbers

* 31. What are the factors that affect this decision? (Please tick all that apply).

☐ Costs of retrofitting ships with scrubbers

☐ The value of the ship

☐ Ship's age

☐ Ship's trading patterns

☐ Costs of engine's modification

☐ Other (please specify)

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

* 32. Has your company chosen a solution to meet the 2020 low sulphur regulations?

◯ Yes

◯ No

Solution(s) to meet 2020 regulations

33. What solution have your company implemented or will be implementing to meet the low sulphur deadline of 2020?

Solution 1

Solution 2

Solution 3

34. Please can you briefly explain the reason(s) behind this solution?

Solution 1

Solution 2

Solution 3

35. Did your company conduct a design and feasibility study when it comes to deciding on the solution to meet the low sulphur regulations? (Please briefly explain the reason(s) behind it).

36. Are there any difficulties involved or do you foresee any difficulties when it comes to implementing your solution(s) to meet the low sulphur regulations?

	Yes	No
Solution 1	◯	◯
Solution 2	◯	◯
Solution 3	◯	◯

37. If you answered yes, can you briefly explain the difficulties?

Solution 1

Solution 2

Solution 3

38. Enforcement level varies from country to country. Will a low standard of enforcement by some countries (port, coastal, flag state authorities) affect your decision-making process in implementing a solution that meets the low sulphur requirements?

◯ Yes

◯ No

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

Solution(s) to meet 2020 regulations

* 39. Can you briefly explain why a low standard of enforcement would affect your decision-making process?

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

40. Have you got any other comments or feedback regarding this questionnaire?

Ships to comply with IMO's 2020 global sulphur cap research questionnaire

End of Questionnaire

Thank you for taking the time to complete this research questionnaire. The researcher truly value the information you have provided.

41. Please indicate your company name to opt out of email reminders to complete this questionnaire. Your company name will not be used in any other way and the information you have provided in this questionnaire will still be kept strictly confidential.

APPENDIX G Equipment manufacturer's questionnaire

Measures to meet IMO's 2020 global low sulphur regulation

Thank you once again for taking time off your busy schedule to participate in this research. The following questionnaire will require approximately *8-10 minutes* to complete.

* 1. Please indicate your position within the company.

- Senior management
- Mid management
- Junior management
- Technical staff
- Other (please specify)

Measures to meet IMO's 2020 global low sulphur regulation

* 2. Is the main product of your company offered to shipowners so that they will be in compliance with the 2020 global low sulphur regulations?

- Yes
- No

(Please briefly explain why your company is offering this product to shipowners?)

Measures to meet IMO's 2020 global low sulphur regulation

* 3. Please briefly give more information about why your company is offering this product?

Measures to meet IMO's 2020 global low sulphur regulation

* 4. What made your company decide to get into the market of providing shipowners with products to comply with the 2020 regulation? (Please tick all that apply).

- [ ] Legislation from governing bodies such as the IMO
- [ ] Demand from shipowners
- [ ] Corporate Social Responsibility (CSR)
- [ ] Other (please specify)

* 5. Please rank the following from 1-4, with 1 being the most important factor that would influence your company to introduce a new product innovation in the market.

- Legislation from governing bodies such as the IMO
- Demand from shipowners
- Corporate Social Responsibility (CSR)
- Other. (based on your answer in Question 4)

* 6. What led your company to initiate a development project to test the technology for removing or reducing SOx from ship's emissions?

* 7. How easy is it to get approval/certification from relevant classification societies on your product?

Easy (1)	Quite easy (2)	Neither easy nor difficult (3)	Quite difficult (4)	Difficult (5)
○	○	○	○	○

* 8. How easy is it for your product to conform to IMO regulations and/or other regulations?

Easy (1)	Quite easy (2)	Neither easy nor difficult (3)	Quite difficult (4)	Difficult (5)
○	○	○	○	○

* 9. What makes your company's product stands out from the rest?

* 10. What do you feel are the biggest challenges for the marine equipment sector in the next few years? (Please tick all that apply)

- [ ] Volatility in the price of materials
- [ ] Global economy
- [ ] Overseas competition
- [ ] Brexit
- [ ] Other (please specify)

Measures to meet IMO's 2020 global low sulphur regulation

Factors affecting product innovation

* 11. As a company, how important is it to receive government support before you consider investing in new technology?

Unimportant (1)	Quite unimportant (2)	Neither unimportant nor important (3)	Quite important (4)	Important (5)
○	○	○	○	○

* 12. Do supporting actions from the government such as providing incentives and concessions have a direct impact on the growth of your company in terms of new innovations?

○ Yes

○ No
(Please briefly explain what could the government have done to support new ventures in your company)

Measures to meet IMO's 2020 global low sulphur regulation

Factors affecting product innovation

* 13. Please briefly explain and provide examples of the supporting actions provided from the government.

Measures to meet IMO's 2020 global low sulphur regulation

Factors affecting product innovation

* 14. *"Innovations are capital oriented. Without the availability of capital, the entrepreneur (organisation) would not be able to purchase land, machine and raw materials for the production of goods".*
To what extent do you agree with this statement?

To a very large extent (1)	To a large extent (2)	Somewhat (3)	To a small extent (4)	To a very small extent (5)
○	○	○	○	○

* 15. Is the availability of capital affecting your company investment in new innovations?

○ Yes

○ No
(Please briefly explain how your company is financing for new innovations?

Measures to meet IMO's 2020 global low sulphur regulation

Factors affecting product innovation

* 16. If finance is a problem, please briefly explain the measures your company is taking to overcome the financial barrier.

Measures to meet IMO's 2020 global low sulphur regulation

Factors affecting product innovation

* 17. How is your company planning to fund growth over the next few years? (Please tick all that apply).

- [ ] Cash reserves
- [ ] Cash flow finance
- [ ] Asset finance
- [ ] Equity
- [ ] Joint venture
- [ ] Trade finance
- [ ] Debt
- [ ] Partnership
- [ ] IPO
- [ ] Not planning
- [ ] Other (please specify)

* 18. To what extent does market demand affect the supply of innovation?

To a very large extent (1)	To a large extent (2)	Somewhat (3)	To a small extent (4)	To a very small extent (5)
○	○	○	○	○

* 19. Does market demand for a particular technology influence your company's decision to enter the market?

○ Yes

○ No
(Please briefly explain your company's reason for not entering the market?

Measures to meet IMO's 2020 global low sulphur regulation

Factors affecting product innovation

* 20. Please briefly explain why your company is influenced to enter the market.

Measures to meet IMO's 2020 global low sulphur regulation

Factors affecting product innovation

* 21. To what extent do you think social environment has an impact on entrepreneurial growth?

To a very large extent (1)	To a large extent (2)	Somewhat (3)	To a small extent (4)	To a very small extent (5)
◯	◯	◯	◯	◯

* 22. Does social environment affect entrepreneurial activities within your company?

◯ No

◯ Yes
(Please briefly explain how it affect your company)

* 23. How important are social environment factors towards promoting innovation activities within your company?

Unimportant (1)	Quite unimportant (2)	Neither unimportant nor important (3)	Quite important (4)	Important (5)
◯	◯	◯	◯	◯

* 24. Does your company's Corporate Social Responsibility (CSR) influence the level of innovation within your company?

◯ No

◯ Yes
(Please briefly explain)

* 25. Do you consider your company to be a first-mover within your market segment (with regards to introducing new technology in complying with the 2020 global low sulphur regulations)?

◯ Yes

◯ No

Measures to meet IMO's 2020 global low sulphur regulation

Factors affecting product innovation

* 26. If you answered yes, on a scale of 1 to 5, with 5 being the highest, how much risk does your company accept when introducing new innovation?

High (1)	Moderately high (2)	Moderate (3)	Moderately low (4)	Low (5)
○	○	○	○	○

Measures to meet IMO's 2020 global low sulphur regulation

27. Have you got any other comments or feedback regarding this questionnaire?

Measures to meet IMO's 2020 global low sulphur regulation

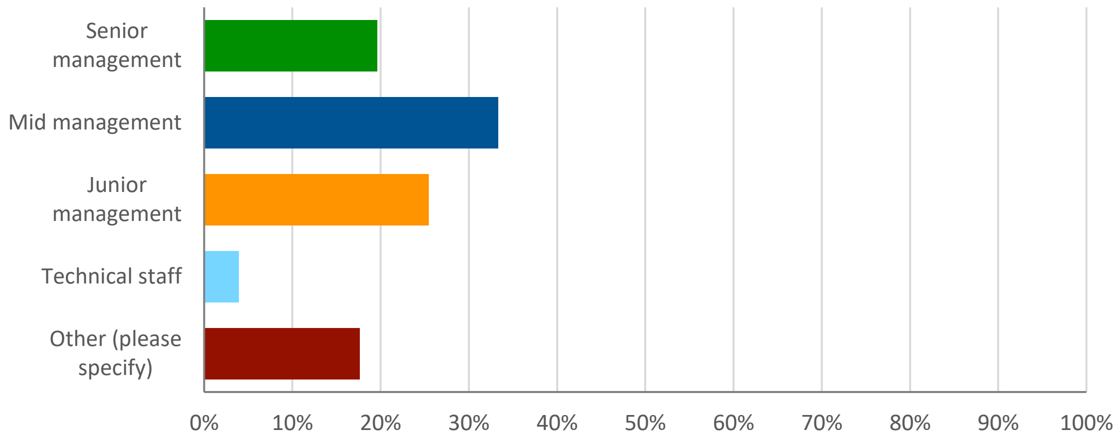
End of questionnaire

Thank you for taking the time to complete this research questionnaire. The researcher truly value the information you have provided.

28. Please indicate your company name to opt out of email reminders to complete this questionnaire. Your company name will not be used in any other way and the information you have provided in this questionnaire will still be kept strictly confidential.

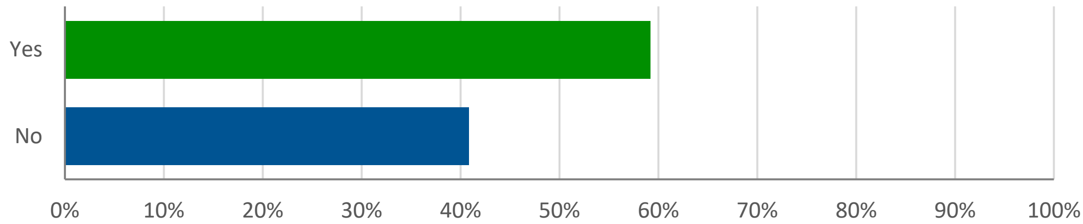
APPENDIX H Results (ship-owner's questionnaire)

Question 1:



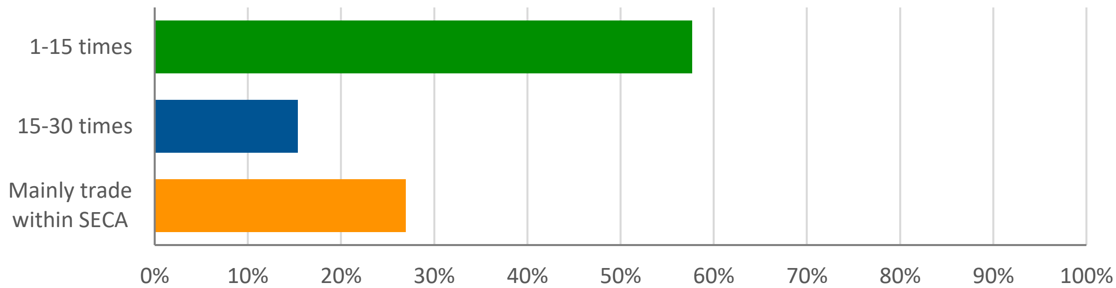
Please indicate your position within the company.

Question 2:



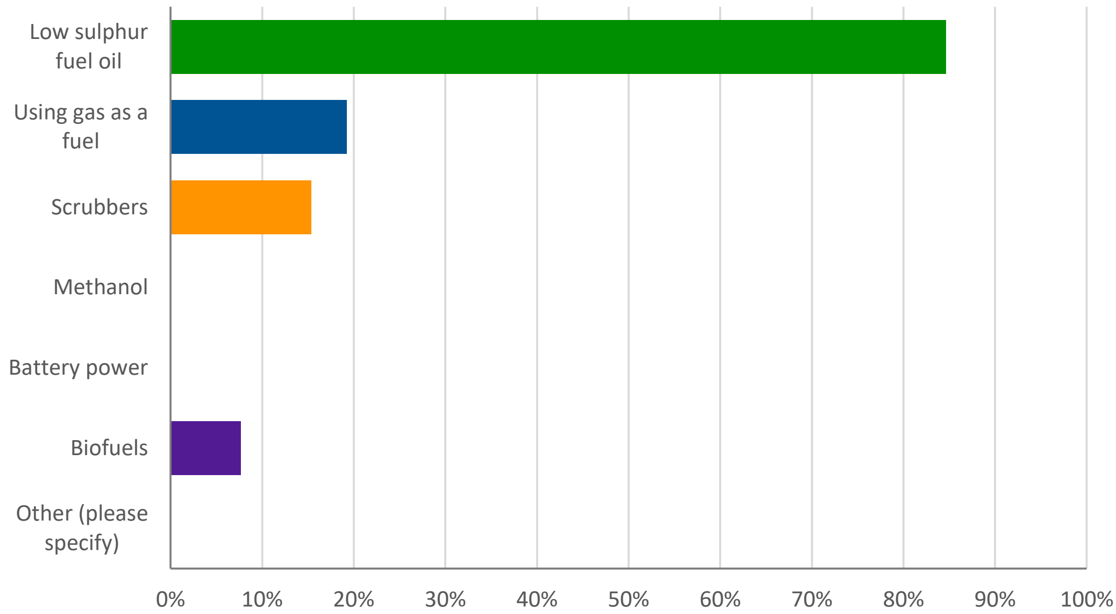
Are any of your company's fleet trading in the designated SECAs of the Baltic Sea or the North Sea?

Question 3:



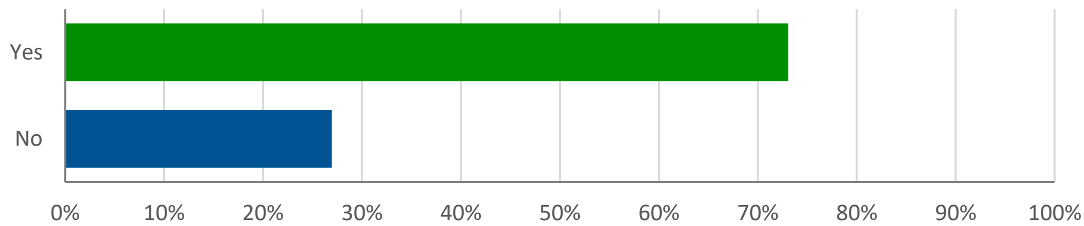
In the course of a month, how often does your company's fleet trade in these areas?

Question 4:



How does your company comply with the regulation of having less than 0.1 percent sulphur content in fuel when trading in these areas?

Question 5:

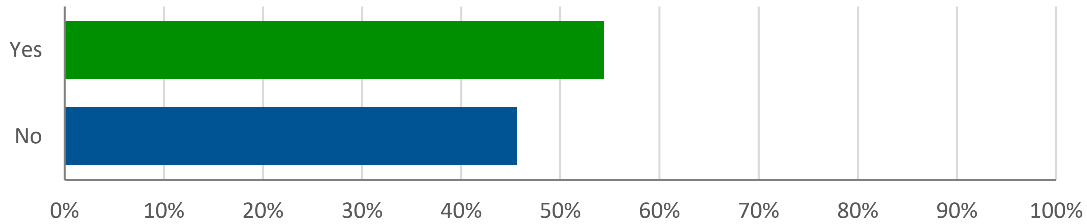


Will your company be employing the same solution to comply with the global 0.5 percent sulphur cap?

Question 6:

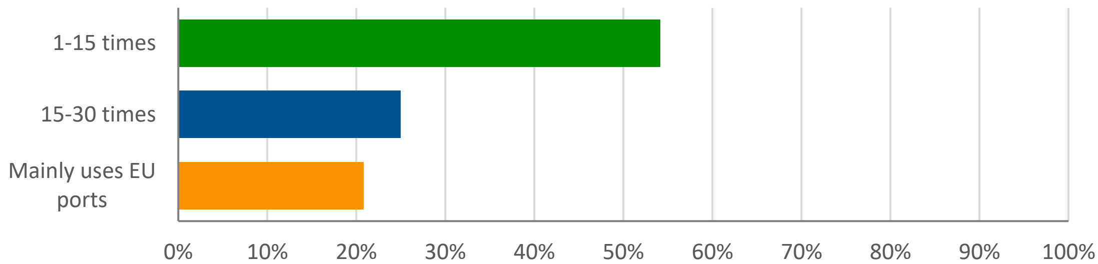
The solution that was referred to by 27 percent of respondents who answered ‘No’ to Question 5 was use of low sulphur fuel oil. The reason given by these respondents to why they would not use low sulphur fuel oil for the 2020 sulphur regulation was because, they were considering using scrubber systems instead. As said by one of the respondents, their company was currently *“investigating the cost-benefit of using scrubber units”*.

Question 7:



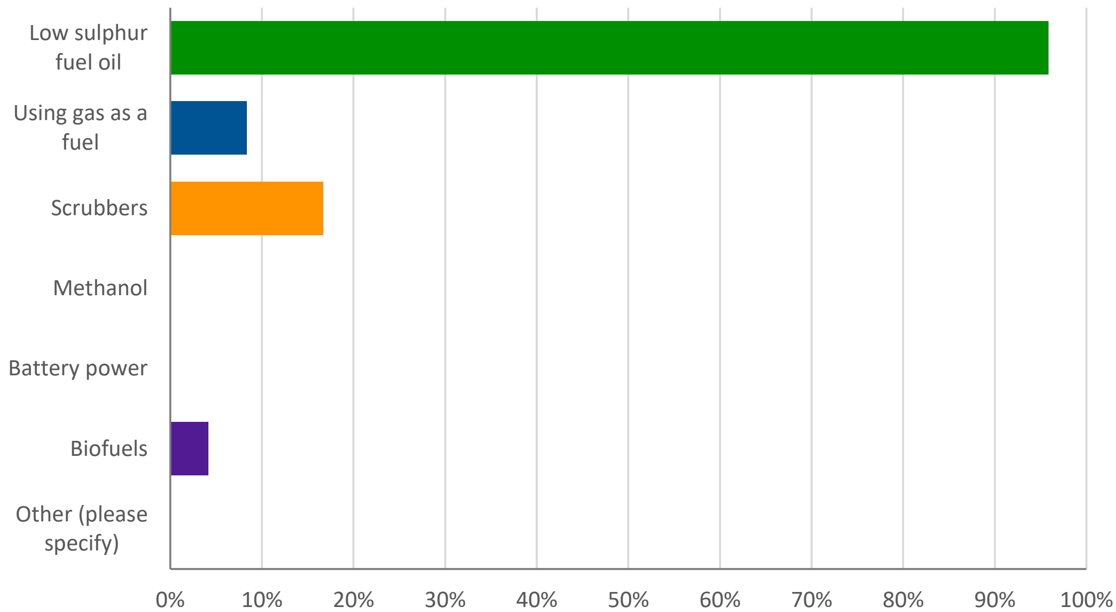
Is your company affected by the above-mentioned requirements (EU Directive 1999/32/EC)?

Question 8:



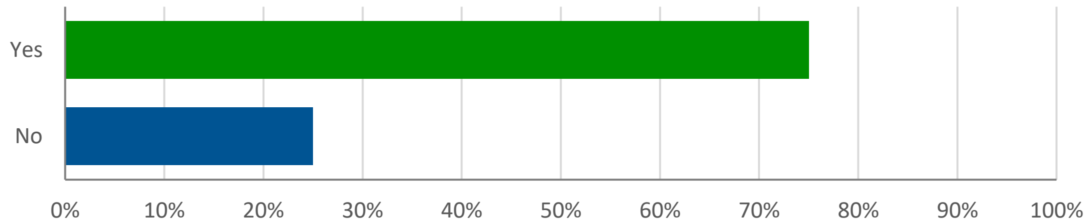
How often does your company's fleet use EU ports in the course of a month?

Question 9:



How does your company comply with the regulation of having less than 0.1 percent sulphur content in fuel?

Question 10:



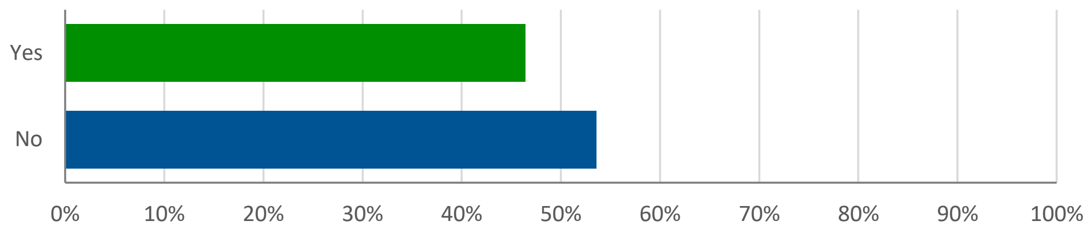
Will your company be employing the same solution to comply with the global 0.5 percent sulphur cap?

The results show that 75 percent of respondents would employ the same solution implemented to comply with the 0.1 percent sulphur limit, for the 0.5 percent regulation coming into force in 2020. The remainder 25 percent of respondents indicated that they would not be employing the same solution to comply with the 2020 global sulphur cap.

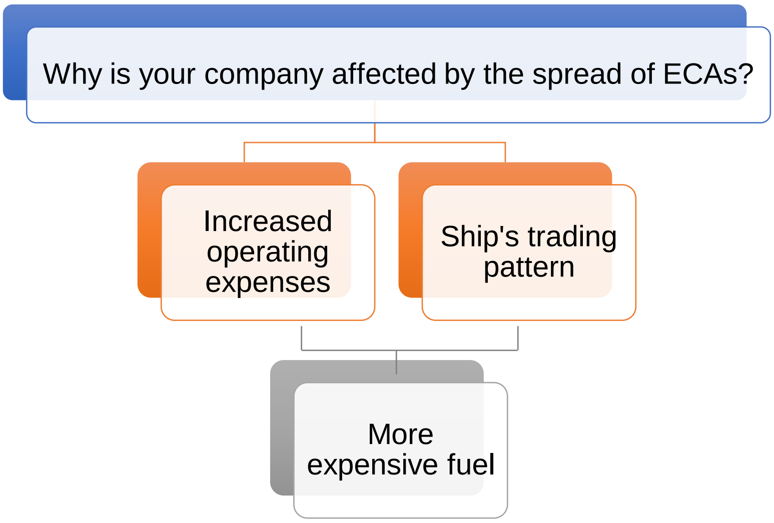
Question 11:

The solution that was referred to by 25 percent of respondents who answered 'No' to Question 10 was use of low sulphur fuel oil. The reason given by these respondents to why they would not use low sulphur fuel oil for the 2020 sulphur regulation was because, they were considering using scrubber systems instead.

Question 12:

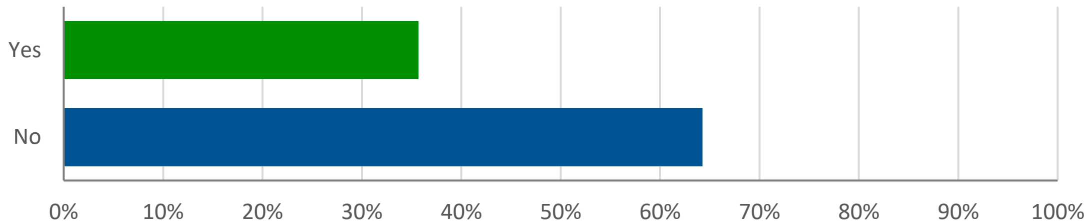


Will your company be affected by the spread of ECAs?



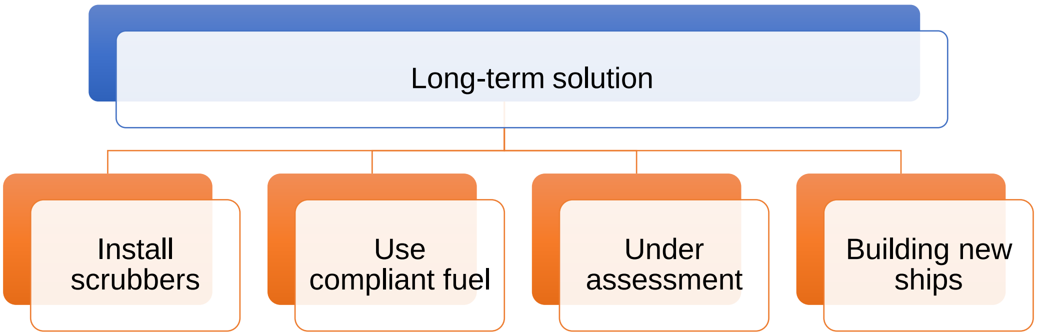
The reasons given by respondents who indicated they would be affected by the potential spread of ECAs were categorised into two themes: increased operating expenses and ship's trading pattern. Both these themes eventually highlighted the same reason to why ship-owners were affected: the spread of ECAs meant ship-owners would be paying for more expensive low sulphur fuel.

<u>Question 13:</u>



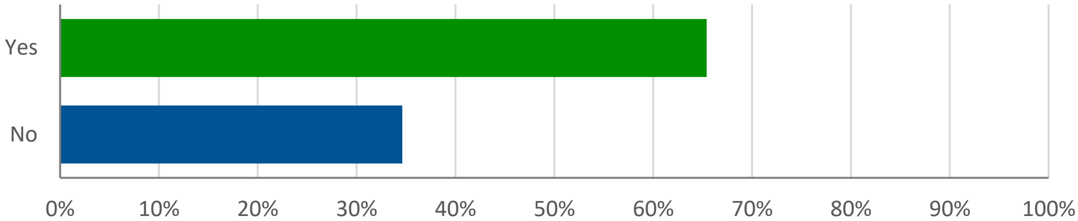
Does this impact your company's decision regarding a solution to comply with the global 0.5 percent sulphur cap?

64 percent of respondents indicated that the potential spread of ECAs have no impact on their decision to adopt a solution to comply with the global sulphur cap. The remainder 36 percent of respondents indicated their decision was affected. These respondents then briefly identified their long-term solution.



The long-term solution given by respondents were categorised into four themes: install scrubbers, use compliant fuel, under assessment and building new ships.

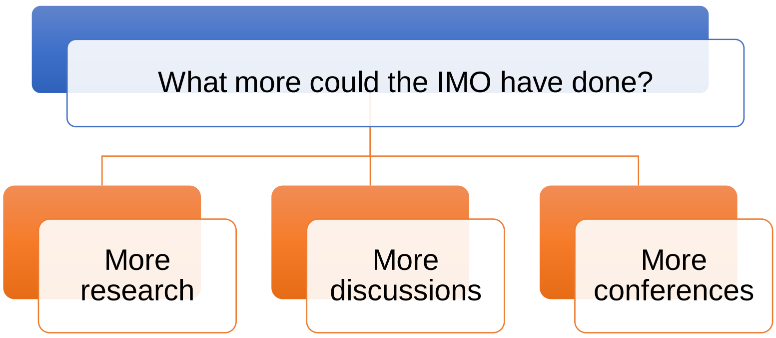
Question 14:



Do you think the IMO have made sufficient efforts to consult with industry players before agreeing to reduce global SOx emissions?

65 percent of respondents indicated that IMO had made sufficient efforts to consult with industry players before agreeing to reduce sulphur emissions in 2020, while the remainder 35 percent of respondents disagreed.

Responses collected from those respondents who disagreed, on what they felt the IMO could have done more, were categorised into three themes.



These respondents felt that more could have been done by the IMO to include ship-owners in that decision. This included having more discussions, research and conferences with industry players. Through these channels, ship-owners and commercial managers would have had more opportunities to voice out their concerns and opinions they had regarding the matter. A long-term plan on how the shipping industry could meet the regulation could have also been discussed through those channels. These responses indicate that some ship-owners are not quite prepared to meet the regulation.

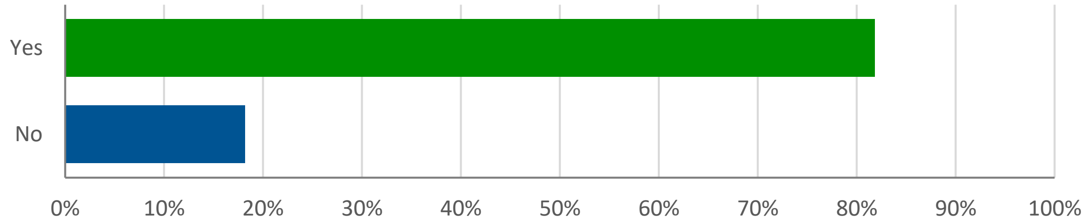
Question 15:

When the 65 percent of respondents who indicated that the IMO had made sufficient efforts (Question 14) were asked to provide with examples, most of them were unable to provide with examples of how the IMO has reached out to industry players as they were *"unsure"*.

The only example identified from the responses was that the IMO had organised several *"talks"* where industry players were able to participate in the discussions. One respondent also said that ship-owners would have had the opportunity to discuss with their respective associations and flag states regarding IMO's agenda before the decision was made.

Another respondent further highlighted that the low sulphur requirement had been known in the shipping industry for *"quite some time"*, which therefore gave ship-owners plenty of time to be prepared. But despite that, the shipping industry was still slow to react and prepare for the requirements. One of the reasons given by the respondent for this was the costs involved to meet the requirements, such as investing in scrubber systems. As the regulation was not enforced back then, the shipping industry was not in a rush to meet the requirements. For these reasons, the respondent felt that the IMO had made sufficient efforts to prepare the industry for the impending regulation.

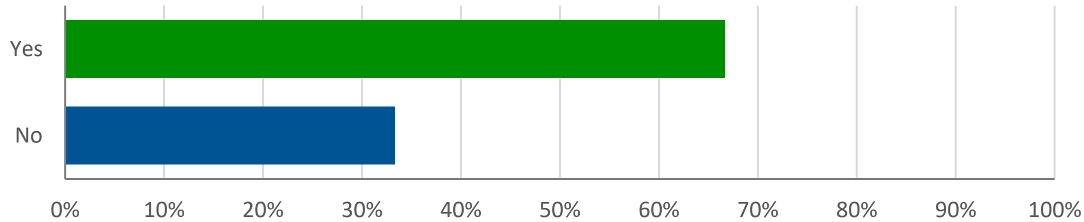
<u>Question 16:</u>



Do you think ship-owners should also have been consulted in the review?

Based on the responses, the majority of respondents (82 percent) felt that ship-owners should have also been consulted in the review that accessed the availability of sufficient compliant fuel oil to meet the global shipping demands in 2020. The remainder 18 percent of respondents indicated otherwise.

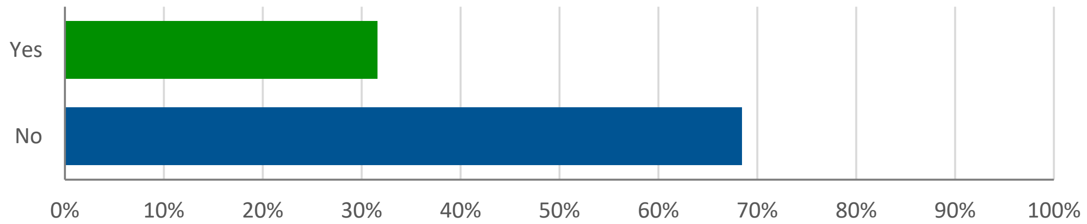
<u>Question 17:</u>



Would your company have preferred the implementation date put back to 1 January 2025?

67 percent of respondents indicated that they preferred the implementation date of the global sulphur regulation pushed back to 1 January 2025, while the remainder 33 percent of respondents were satisfied with the current arrangement.

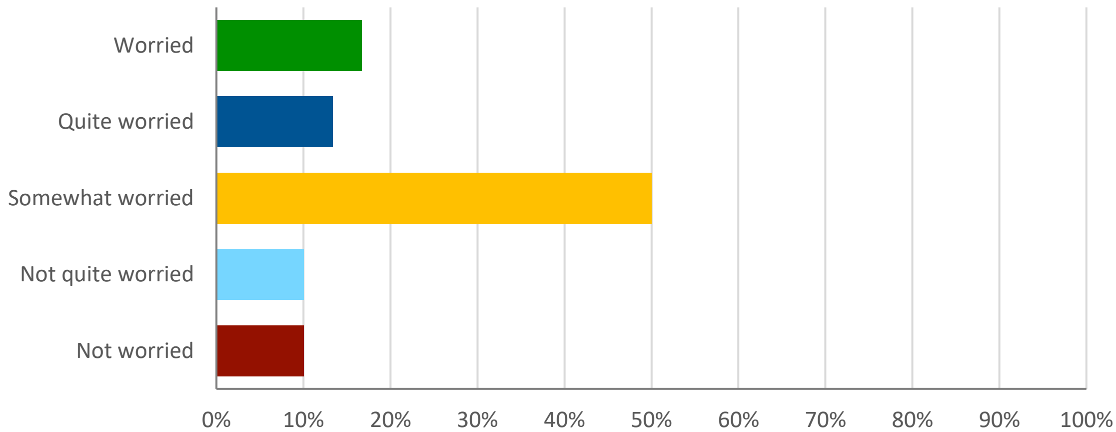
Question 18:



Does the conflicting fuel study affect your company's decision-making process in using low sulphur fuel as a solution?

Based on the responses, almost 70 percent of respondents indicated their decision to use low sulphur fuel as a solution to meet the sulphur regulation, was not affected by the conflicting fuel study. Only 32 percent of respondents indicated their decision-making process would be affected.

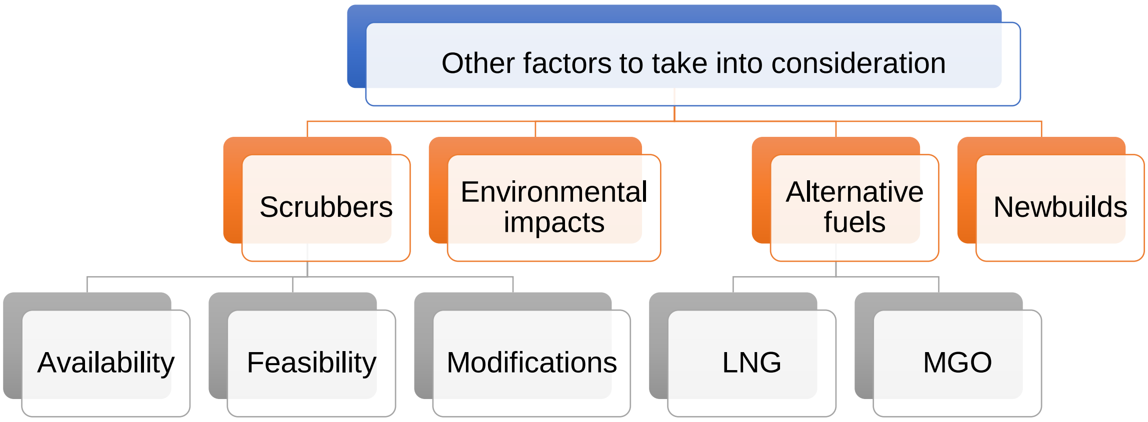
Question 19:



Is your company worried about price fluctuations of low sulphur fuel?

Based on the responses, the majority of respondents (50 percent) were 'somewhat worried' about price fluctuations of low sulphur fuel (LSF).

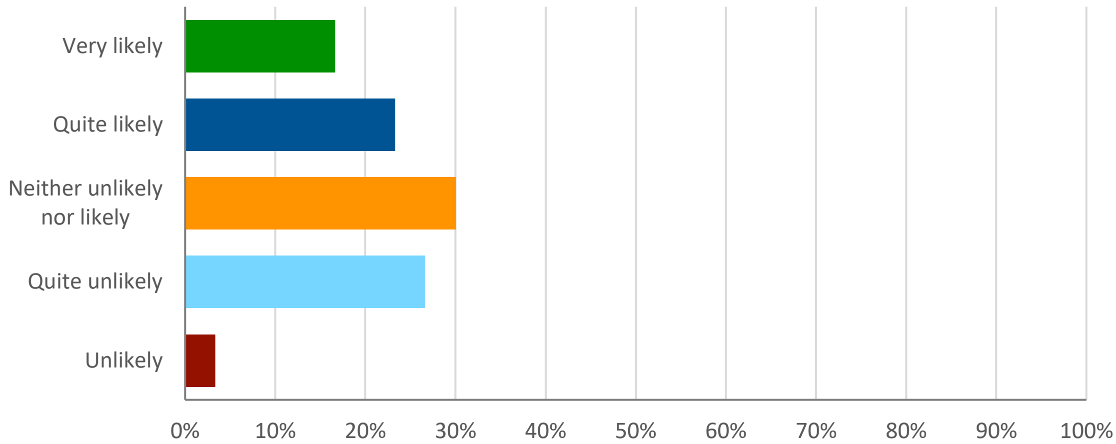
Question 20:



When respondents were asked to list down all factors that were taken into consideration when deciding on solutions to meet the sulphur regulation, their responses were grouped into four main themes. The first identified theme is considering scrubber systems as a solution. This involves looking into issues related to its availability, feasibility and onboard modification works required for its installation. Some ship-owners were also considering other factors which include using alternative fuels such as LNG or MGO, building new energy-efficient ships as a long-term solution, and on the environmental impacts their potential solutions may have.

Most of the other respondents indicated that there were no other factors being taken into consideration by their company, when deciding on solutions to meet the 2020 regulation. One of the respondents further said that their company was already meeting the most stringent regulation for their fleet by having emission levels of less than 0.1 percent. As such, the company is already in compliance with the impending global sulphur cap regulation.

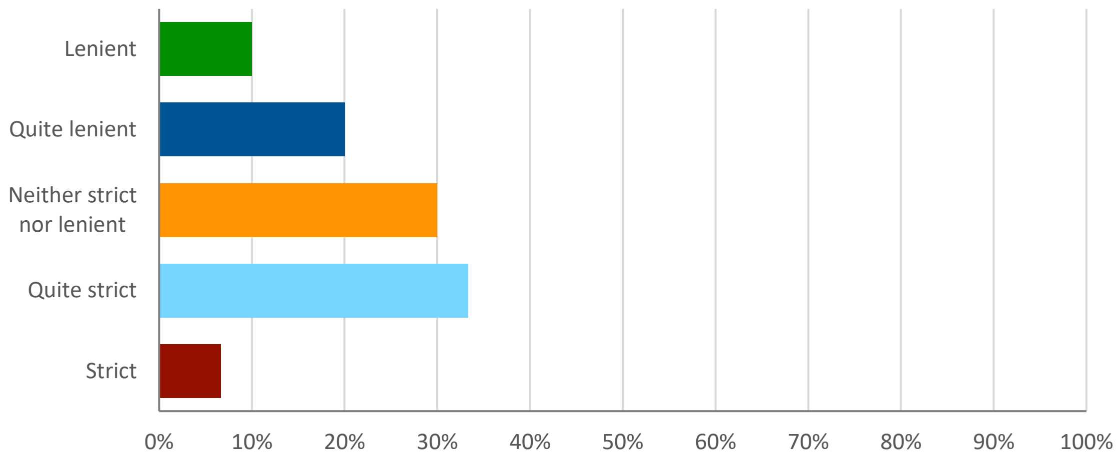
Question 21:



How likely do you think the shipping industry as a whole will be able to meet the lower sulphur requirements before 1 January 2020?

Based on the responses, the majority of respondents (30 percent) indicated that they felt the shipping industry would 'neither unlikely nor likely' be able to comply with the sulphur regulation before its implementation date.

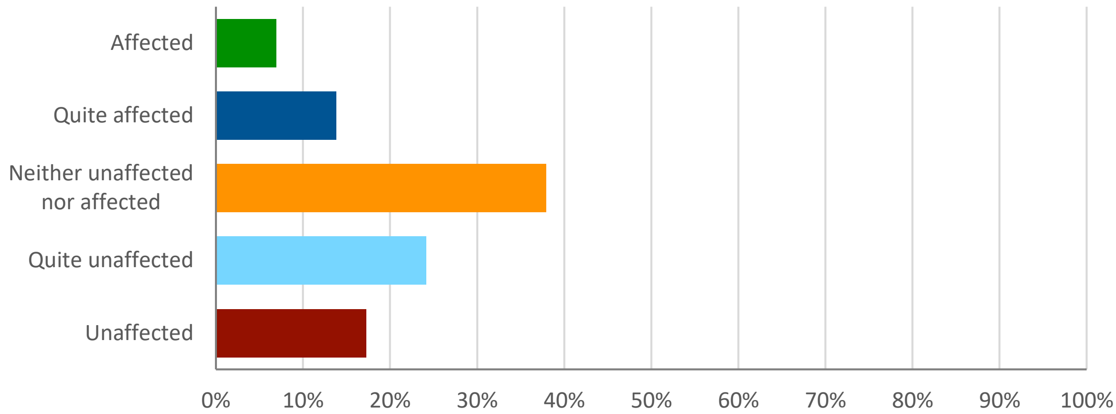
Question 22:



How strictly do you think the shipping industry will enforce the low sulphur regulations on 1 January 2020?

Based on the responses, the majority of respondents (33 percent) indicated that the level of enforcement for the 2020 global low sulphur regulation would be 'quite strict'.

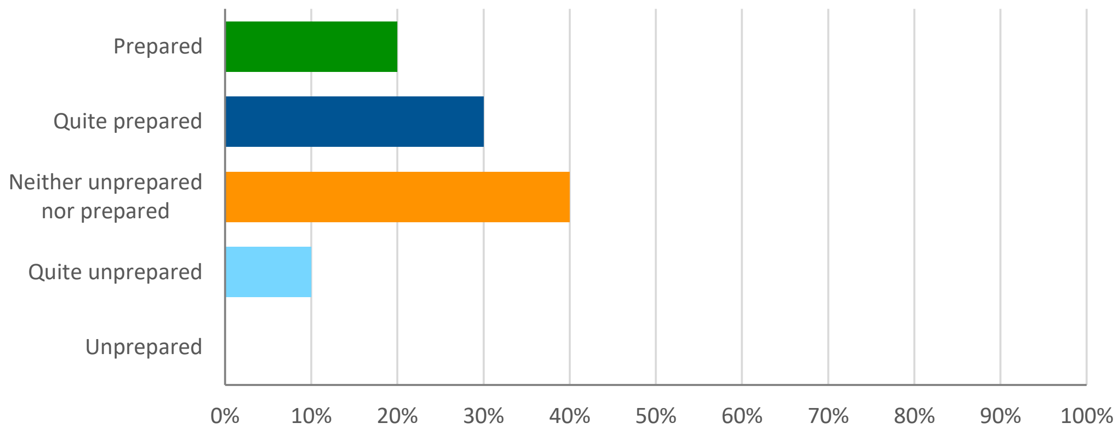
Question 23:



How affected is your company's operations between now and 2020 with regards to the sulphur cap deadline of 1 January 2020?

38 percent of respondents indicated their company's operations between now and 2020 were 'neither unaffected nor affected' by the sulphur cap deadline of 1 January 2020.

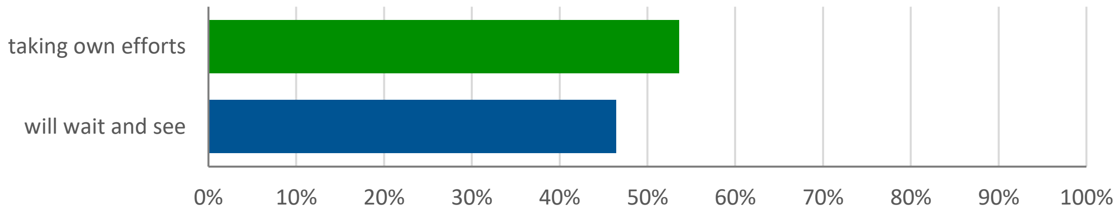
Question 24:



How prepared is your company to be able to meet the lower sulphur cap deadline of 1 January 2020?

When respondents were asked to indicate their company's preparedness in meeting the regulation, the majority of them answered that their company were 'neither unprepared nor prepared'. 20 percent of respondents indicated they were 'prepared' to meet the sulphur cap deadline.

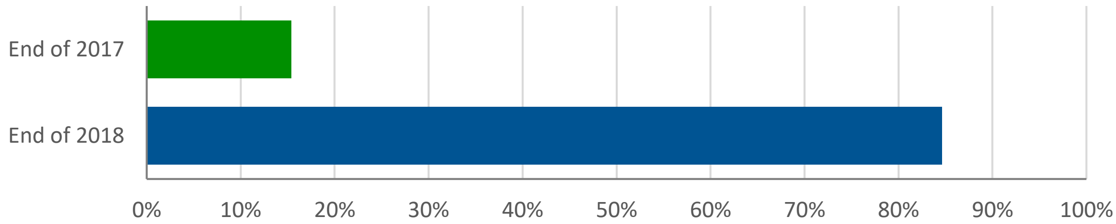
Question 25:



Is your company taking its own efforts to comply, or will wait and see what the industry selects?

54 percent of respondents indicated their company was taking its own efforts to be in compliance with the sulphur regulation, while the remainder 46 percent of respondents would wait for an outcome from the industry.

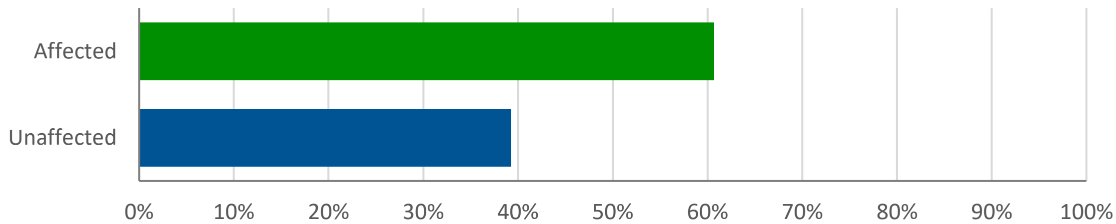
Question 26:



If your company is waiting for an outcome from the industry, how long will you be willing to wait before making a decision?

Out of the 46 percent of respondents who indicated they would wait for an outcome from the industry (Question 25), more than 80 percent of them indicated they were willing to wait until the end of 2018 before deciding on a solution.

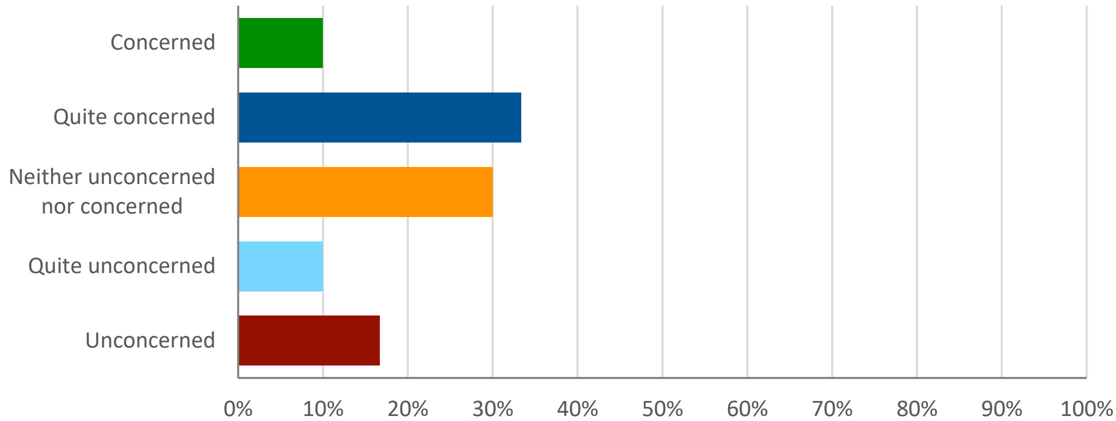
Question 27:



Does placing ships on off-hire affect your company's decision-making process in choosing scrubbers?

Based on the responses, 61 percent of respondents indicated that placing their ships on off-hire affected their decision-making process in selecting scrubbers as a solution. Only 39 percent of respondents indicated they were unaffected.

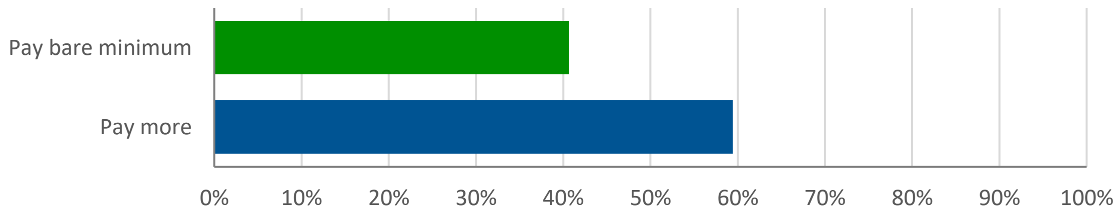
Question 28:



As the 2020 deadline nears, how concerned are you with the availability of repair docks or dry-docks for the installation of scrubbers?

Based on the results, 33 percent of respondents indicated they were 'quite concerned' with the availability of repair docks or dry docks for scrubber unit installation.

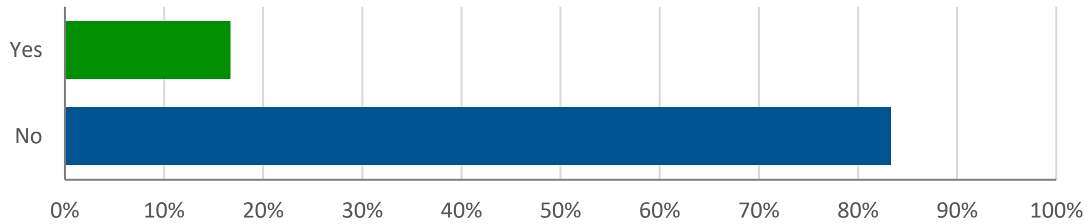
Question 29:



Will your company pay more for a proven technology (certainty and quality) or opt for cheaper, unproven technology?

Based on the results, the majority of respondents (59 percent) indicated they would pay more for a proven technology, compared to the remainder 41 percent of respondents who would pay the bare minimum for an unproven technology.

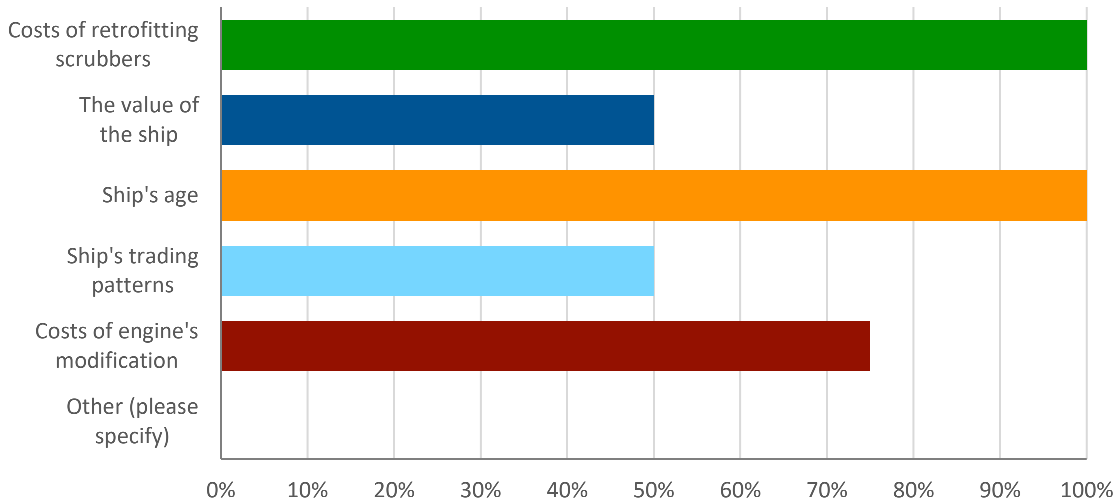
Question 30:



Is your company considering scrapping ships early as a solution to meeting the lower sulphur regulations?

More than 80 percent of respondents indicated their company were not considering scrapping ships early as a solution to meet the global sulphur regulation. Only 17 percent of respondents indicated they were considering this option.

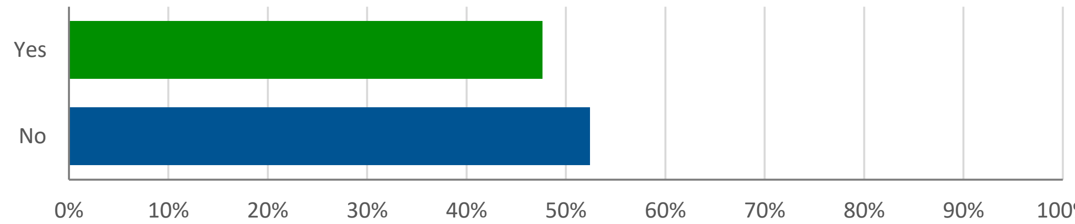
Question 31:



What are the factors that affect this decision?

The key factors influencing all 17 percent of respondents (Question 30) to consider scrapping their ships early were due to the 'costs of retrofitting scrubbers' and the 'ship's age'. Other factors selected by respondents also include the 'costs of engine's modification' (75 percent), 'the value of the ship' (50 percent) and 'ship's trading patterns' (50 percent).

Question 32:

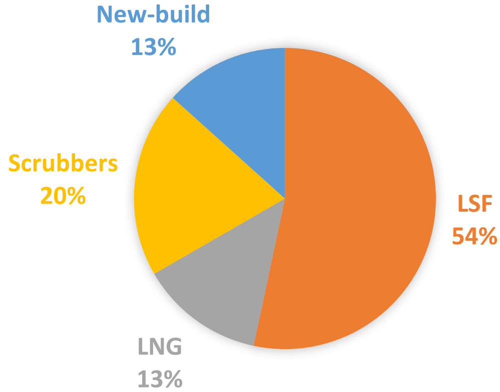


Has your company chosen a solution to meet the 2020 low sulphur regulations?

Out of all respondents who participated in this research questionnaire, only 48 percent of them had chosen a solution to meet with the 2020 global sulphur cap. The remainder 52 percent of respondents on the other hand, had yet to find a solution for their ships.

Questions 33 to 39 represent answers only from respondents (48 percent) whose company had chosen a solution to comply with the 2020 global low sulphur regulation.

Question 33:



What solution have your company implemented or will be implementing to meet the low sulphur deadline of 2020?

Out of the 48 percent of respondents who had chosen a solution to comply with the sulphur regulation, 54 percent of them opted using low sulphur fuel (LSF). Other solutions identified from the responses are using scrubber systems (20 percent), using liquified natural gas (LNG) (13 percent) and construction of new ships (13 percent).

<u>Question 34:</u>

Answers given by respondents on the reason behind implementing their chosen solution are as follows:

Using LSF. Ship-owners who opted to use LSF to comply with the sulphur regulation said that it was the most practical solution that suits their ship's operations. Ship's age is another factor for using LSF, as ship-owners are not able to justify investing on ships that are nearing its life expectancy. Some of the respondents also said that retrofitting scrubbers onboard was not a practical solution for their ships.

Using scrubber systems. Ship-owners who opted to use scrubber systems as a solution, said that it made more economical sense to retrofit their new, modern ships with a long lifetime ahead, with the units to comply with the sulphur regulation.

Using LNG. Respondents who opted for LNG, said that their company was better suited to use it as a solution to comply with the sulphur regulation.

New-builds. Respondents who constructed new ships as a solution to comply with the sulphur regulation, said that it was a more feasible option for their company.

Question 35:

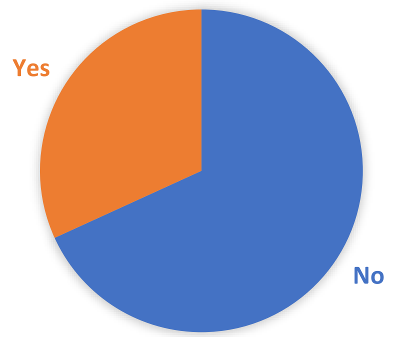
Did your company conduct a design and feasibility study when it comes to deciding on the solution to meet the low sulphur regulation?

50 percent of respondents indicated that they did not conduct a design and feasibility study, when deciding on a solution to comply with the sulphur regulation, while the remainder 50 percent of respondents did.

Only one respondent explained the reason for conducting a design and feasibility study. The reason was because the company wanted to investigate the most cost-effective solution to implement on their ships.

However, it is difficult to determine if ship-owners who did not conduct a design and feasibility study, adopted a solution based on their observation of current trend in the industry. This is due to the incomplete and lack of responses provided by respondents. Overall, it is evident that there are some ship-owners who puts in effort to decide on a solution, and there are others that does not.

Question 36:



Are there any difficulties involved or do you foresee any difficulties when it comes to implementing your solution?

The majority of respondents (68 percent) indicated no difficulties were encountered when it came to implement their selected solution. Only 32 percent of respondents indicated they encountered some difficulties.

Question 37:

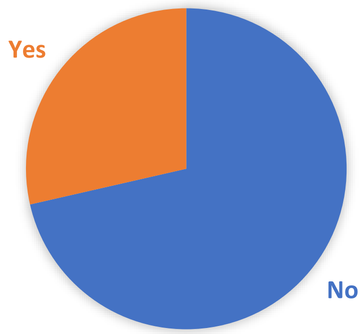
Based on the responses, two themes were identified when respondents who indicated they encountered difficulties (Question 36), were asked to provide with examples. The two themes are ‘supply of fuel’ and ‘selection process’.

Respondents who opted to use LSF said their difficulties were related to its supply. These respondents were concerned that the supply of LSF may not be sufficient to meet global demand when the sulphur regulation comes into force.

As for respondents who retrofitted their ships with scrubber systems, the difficulties faced was during the selection process. These respondents had to consider the costs associated with installing scrubbers and the age of the ship. In other words, the difficulties were associated with justifying retrofitting scrubber systems on ageing ships.

Overall, it is evident that there are factors that needs to be considered by ship-owners when deciding on a solution to implement on their ships. These factors may be useful to ship-owners who have yet to decide on a solution.

Question 38:



Did the potentially low standard of enforcement affected your decision-making process when selecting your chosen solution?

71 percent of respondents indicated their decision-making process to select a solution, was not affected by the potentially low standard of enforcement. Only 29 percent of respondents indicated they were affected.

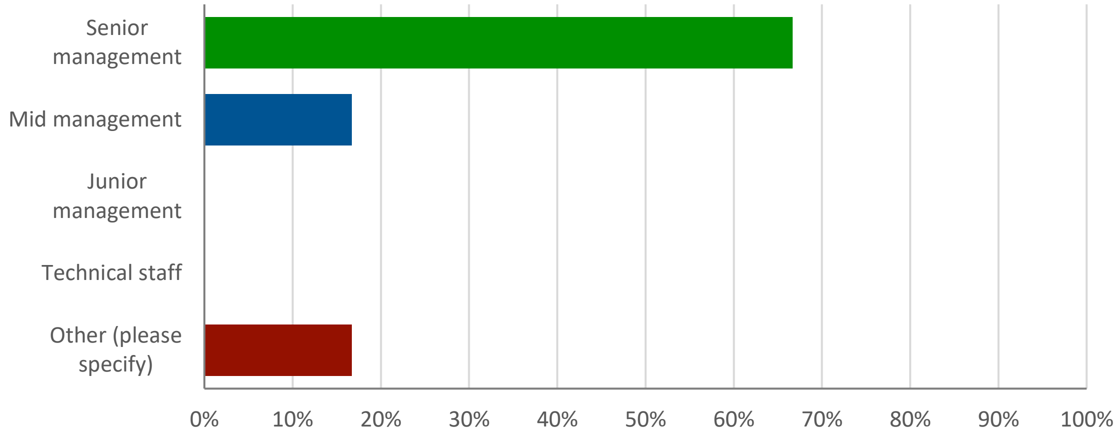
Question 39:

Only one theme was identified from the responses provided by respondents who indicated low enforcement level affected their decision-making process (Question 38). The theme is ‘unfair advantage’. These respondents were concerned that low enforcement level may result in some ship-owners to avoid implementing solutions onboard. This may consequently result in market distortions and creates an uneven playing field for ship-owners who have taken efforts to comply with the regulation.

Although these are valid points to why low enforcement level concerns ship-owners, the responses did not highlight whether low enforcement level affects the type of solution being implemented, or even in a solution being adopted.

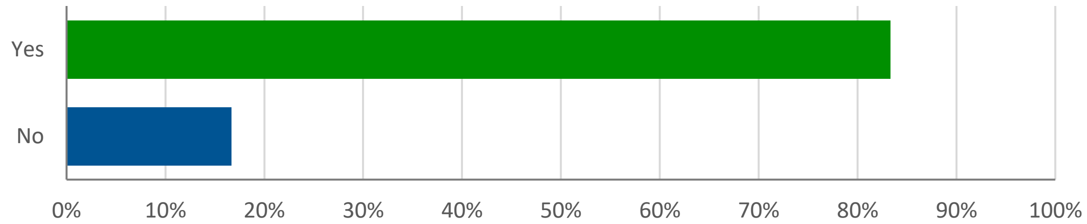
APPENDIX I Results (equipment manufacturer's questionnaire)

<u>Question 1:</u>



Please indicate your position within the company

<u>Question 2:</u>



Is the main product of your company offered to ship-owners so that they will be in compliance with the 2020 regulation?

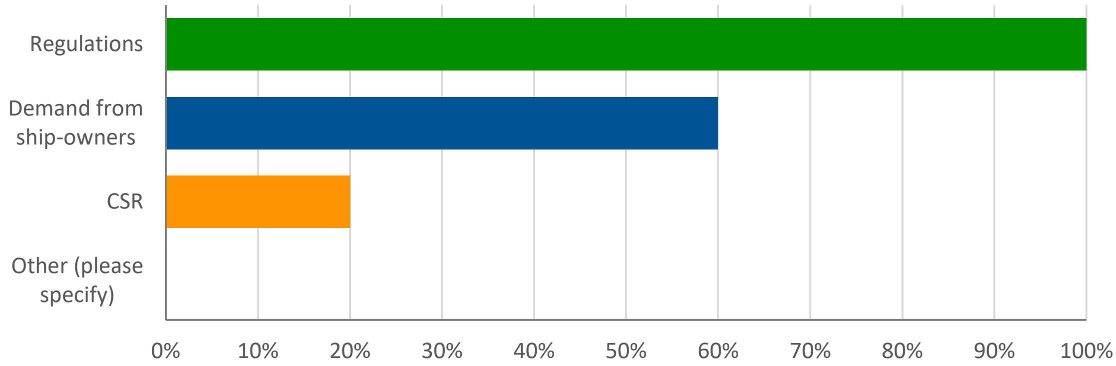
83 percent of respondents indicated their main product was offered to ship-owners to comply with the global sulphur regulation. The remainder 17 percent of respondents on the other hand, were offering products for the overall reduction in fuel consumption and related emissions by ships.

<u>Question 3:</u>

Responses provided by 83 percent of respondents (Question 2) on the reason their companies were offering products to meet the sulphur regulation, were grouped into two themes. The two themes are 'to make profits' and 'to assist ship-owners'.

As such, these two factors may represent the drivers that encourage these manufacturing companies to innovate.

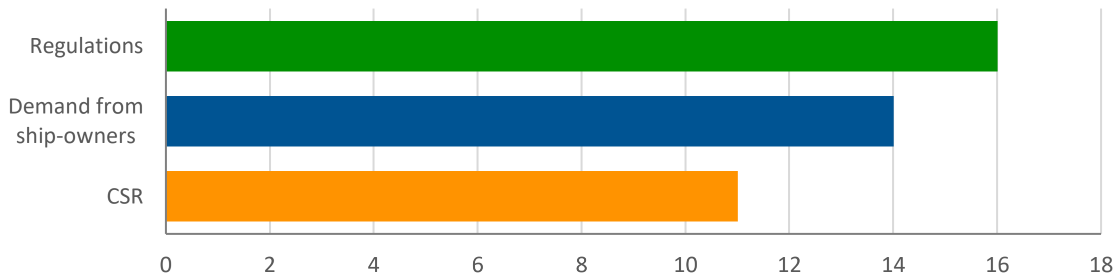
Question 4:



What made your company decide to get into the market of providing ship-owners with products to comply with the 2020 regulation?

The results show that all respondents entered the market because of IMO sulphur regulations. Other reasons for entering the market as indicated by respondents are because of ‘demands from ship-owners’ (60 percent) and company’s corporate social responsibility (CSR) (20 percent).

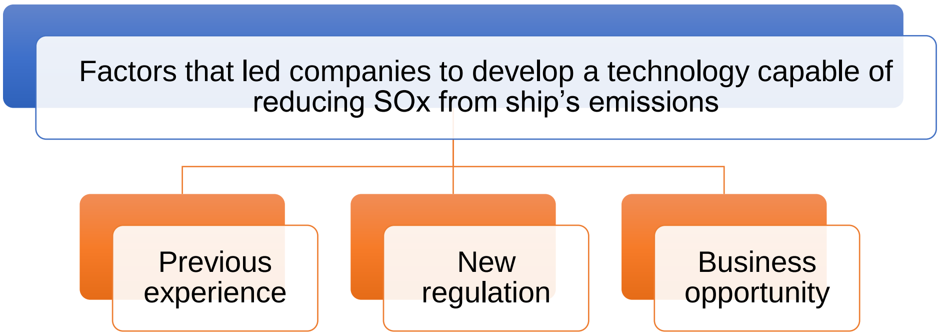
Question 5:



Rank the most to the least important factor that would influence your company to introduce a new product innovation.

When respondents were asked to rank in order of the most important to the least important factor influencing their company to introduce a new product, regulation was ranked as the most important factor, followed by demand from ship-owners, and CSR being the least important factor.

Question 6:



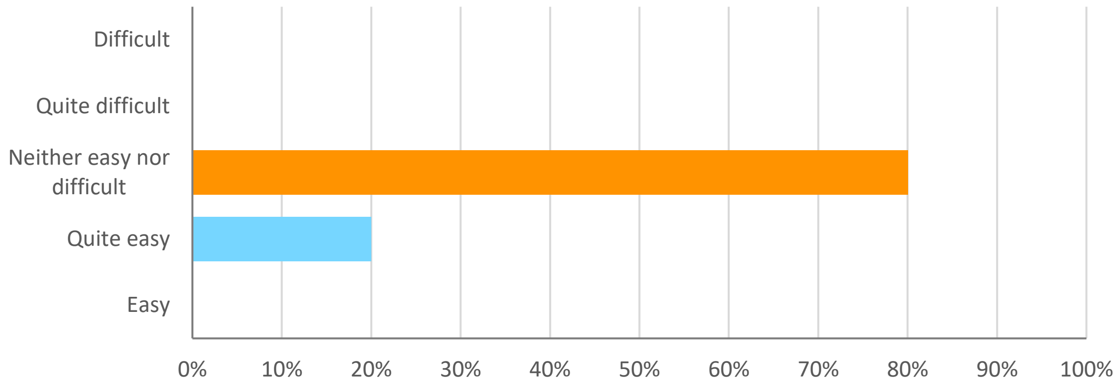
Responses provided by respondents on reasons their companies initiated a development project were categorised into three themes. The three themes are 'previous experience', 'new regulation' and 'business opportunity'.

Previous experience. According to one respondent, their company had dealt with similar technology in the past. However, it was only specific to land uses. As such, their company was encouraged to try and commercialise the technology for sea applications.

New regulation. For some respondents, it was new regulations that has encouraged them to initiate a development project. This was in relation to the 2020 global sulphur regulation which resulted in increased demand for products that reduces fuel consumption and related emissions from ship-owners.

Business opportunity. Companies were also encouraged to initiate a development project based on a gap they saw in the market. As such, these companies are trying to see if they are able to fill that gap in the market with their products.

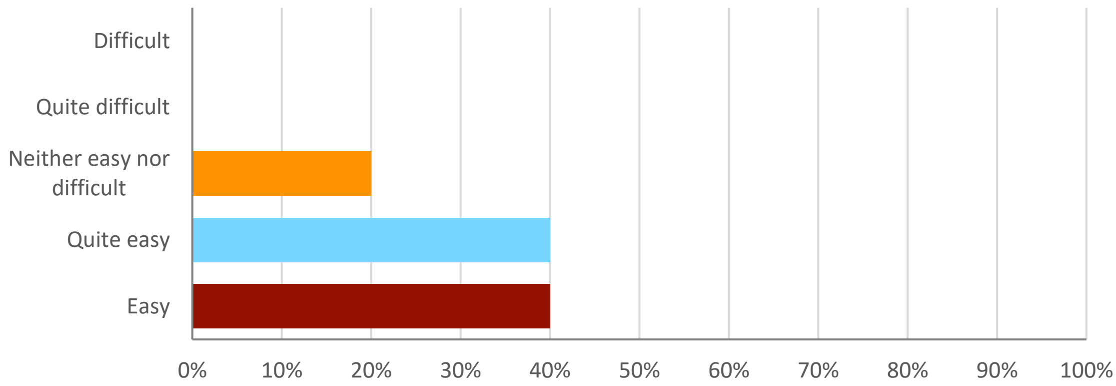
Question 7:



How easy is it to get approval/certification from relevant classification societies on your product?

The majority of respondents (80 percent) indicated it was ‘neither easy nor difficult’ to get approval or certification from classification societies on their products. Furthermore, 20 percent of respondents indicated the process was ‘quite easy’. Therefore, getting approval or certification from classification society may be considered as a factor that does not discourage manufacturing companies from innovating.

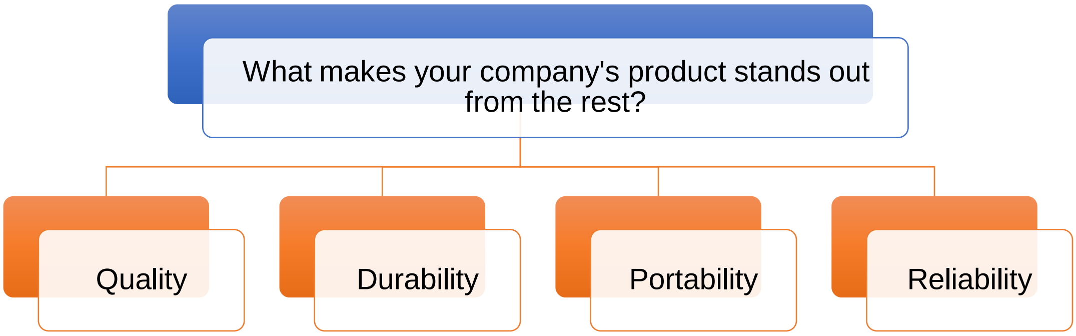
Question 8:



How easy is it for your product to conform to IMO regulations?

Responses were split between ‘quite easy’ and ‘easy’ when respondents were asked on how easy or difficult it was for their product to conform to IMO regulations. The results show that most manufacturing companies face no difficulties when developing a product to meet IMO’s low sulphur regulation. In other words, the standards set by the IMO was easy for manufacturing companies to achieve though their product innovation.

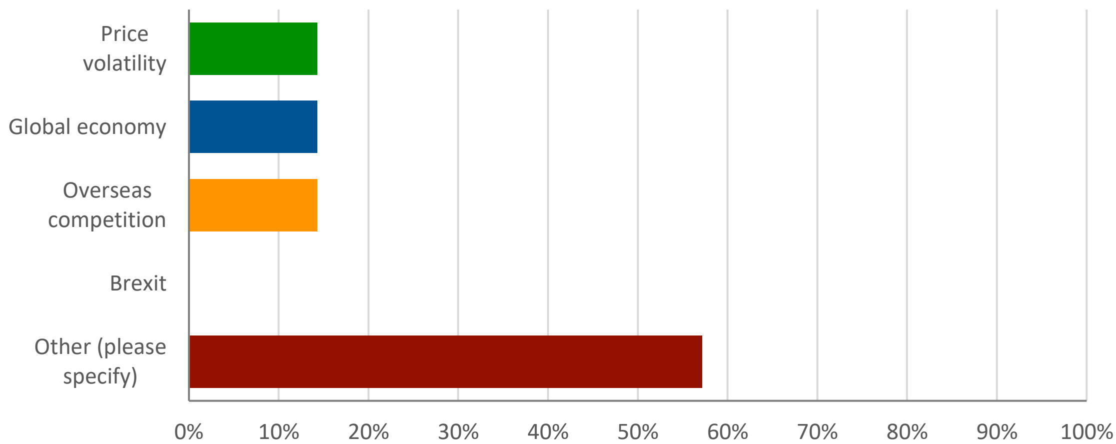
<u>Question 9:</u>



Responses provided by respondents on what made their company's product stood out from their competitors, were categorised into 4 themes. The four identified themes are quality, durability, portability and reliability.

Based on the responses, it is evident that there is a strong level of competition among manufacturing companies as there are many features that makes each product different from the rest. As such, competition may be considered as a factor encouraging product innovation in equipment manufacturing companies.

<u>Question 10:</u>

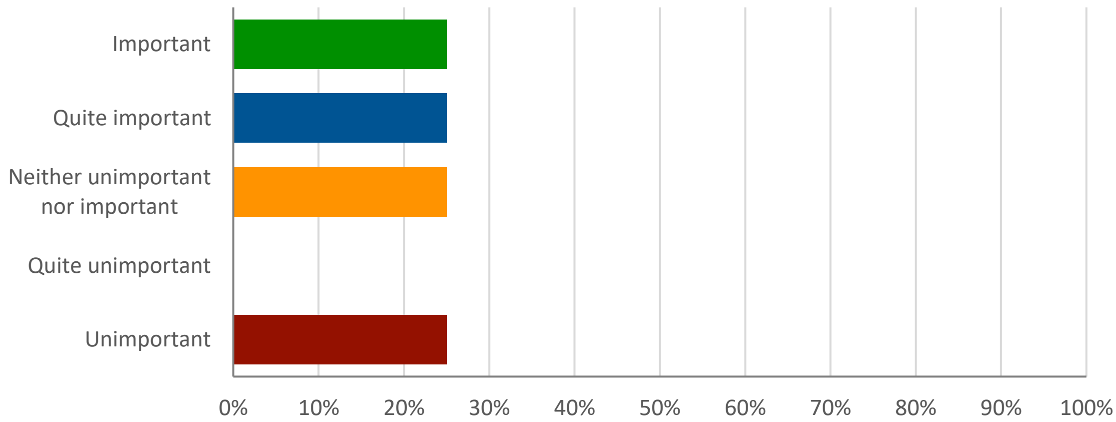


What do you feel are the biggest challenges for the marine equipment sector in the next few years?

14 percent of respondents selected ‘price volatility’, ‘global economy’ and ‘overseas competition’ to be the challenges faced by the marine equipment sector in the next few years. Some of the respondents also specified other challenges that the sector may face: uncertainty in fuel pricing and availability, oversupply of ships and ship-owners’ adaptation to the 2020 regulation.

As such, these are the challenges facing the sector in the coming years. These challenges may have an impact on the number of new product innovation from being introduced in the market.

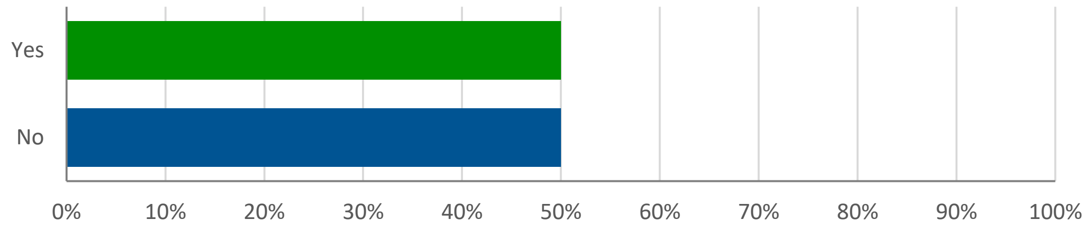
<u>Question 11:</u>



As a company, how important is it to receive government support before you consider investing in new technology?

25 percent of the respondents indicated receiving government support is an ‘important’ factor that would influence their decision to invest in new technology. Receiving government support is also ‘quite important’ to another 25 percent of the respondents.

Question 12:

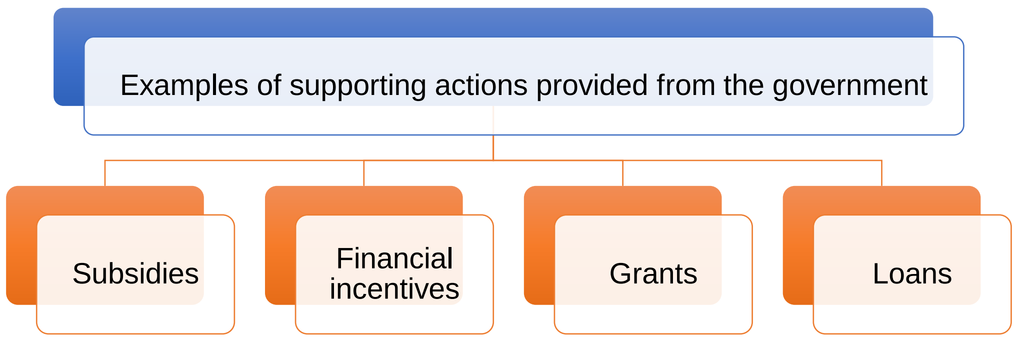


Do supporting actions from governments have a direct impact on the growth of your company in terms of new innovations?

50 percent of respondents indicated that supporting actions from governments have a direct impact on the growth of their company in terms of new innovations. The remainder 50 percent of respondents indicated otherwise.

One of the respondents who indicated 'No', said that it was not the government's responsibility to make available any form of support or incentives to encourage manufacturing companies to innovate. Another respondent further said that it was better for them as a company and to their customers to have full control over their development and success, instead of depending on receiving government supports. This allowed their company to innovate freely, where their innovation activities are not affected from the lack of government support.

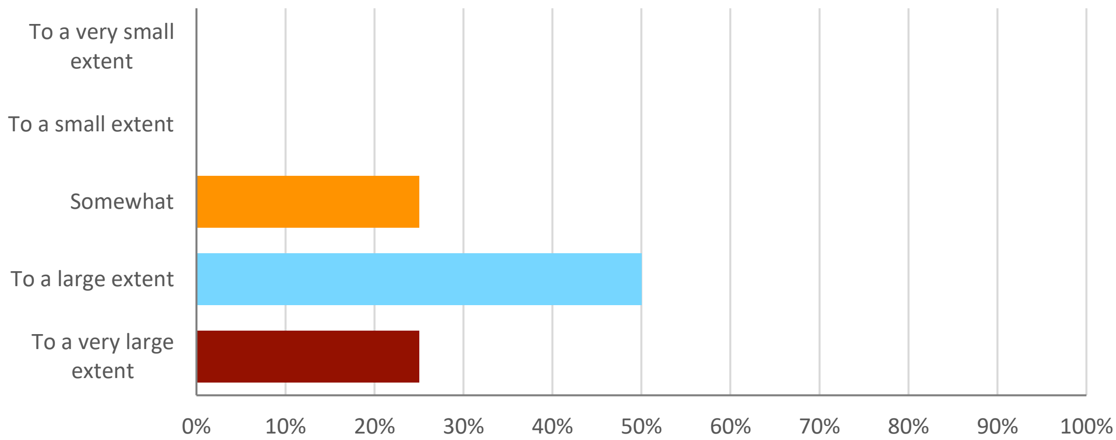
Question 13:



Four examples of supporting actions provided from the government were identified from the responses given by respondents. They are subsidies, financial incentives, grants and loans.

According to respondents, financial incentives such as receiving tax support for early adopters of new technology, is one of the factors encouraging companies to innovate. Government subsidies were also provided to companies that would invest in new clean technology. This further encouraged innovation in manufacturing companies. In addition, some governments were also distributing grants and loans to technology developers, in order to encourage more innovative products. Based on the responses, it is evident that there are many different types of support being offered by governments to encourage innovation in manufacturing companies.

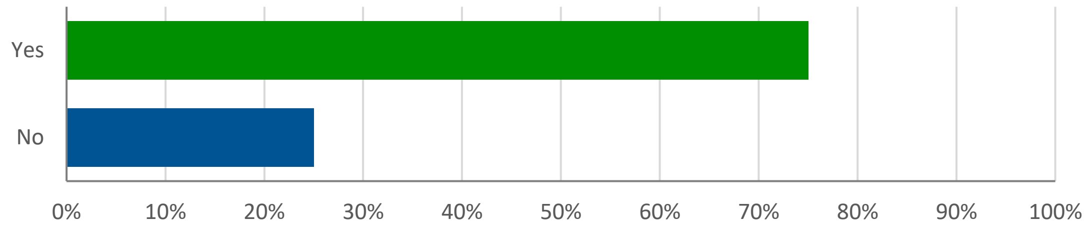
<u>Question 14:</u>



To what extent do you agree innovations are capital oriented?

50 percent of respondents agree ‘to a large extent’ that innovations are capital oriented, as companies need to have the financial means to purchase machines and raw materials for the production of goods. Another 25 percent of respondents indicated they agreed ‘to a very large extent’.

Question 15:



Is the availability of capital affecting your company's investment in new innovations?

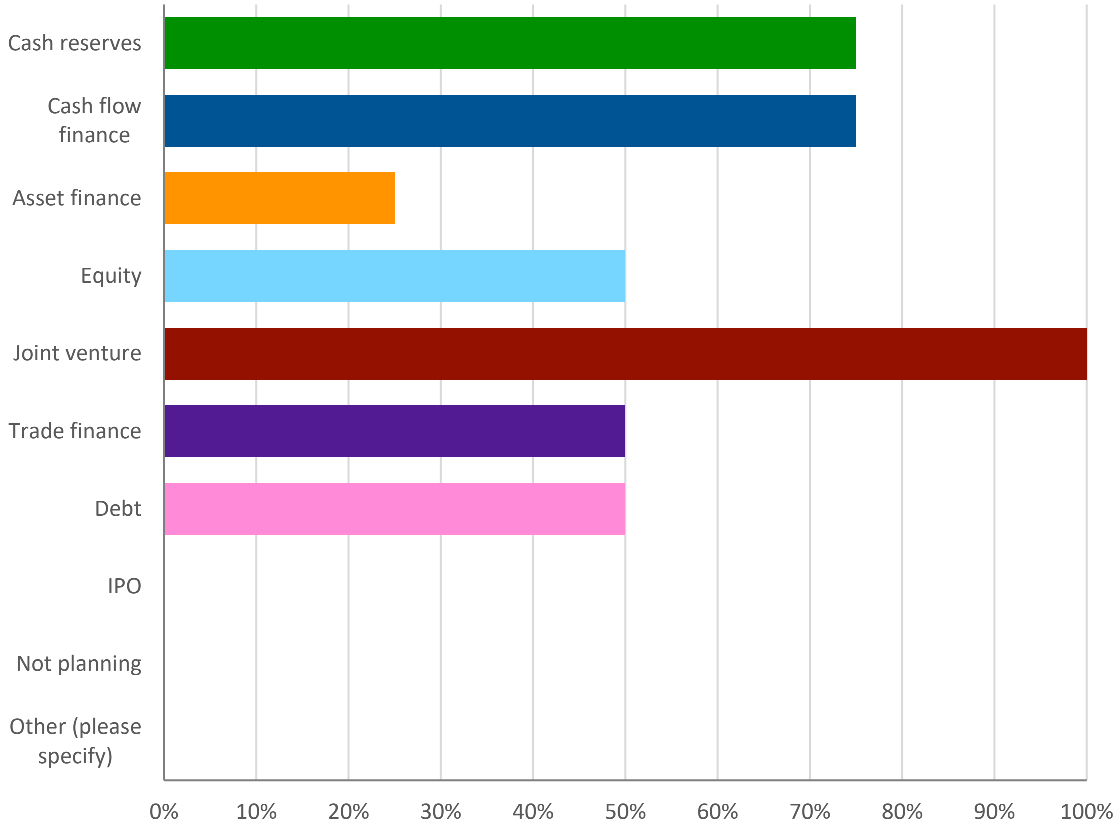
The majority of respondents indicated their company's investment in new innovations were affected by the availability of capital.

Only 25 percent of respondents indicated their investments were not affected. One of the respondents said that it was because their company had set aside funds to support their innovation activities.

Question 16:

When respondents were asked to indicate the measures undertaken by their company to overcome financial barriers, only two measures were identified from the responses provided. The two measures to finance new innovations are 'merger and acquisition' and 'strategic alliance'. As such, these are the solutions that may be used to encourage other capital-restricted companies to innovate.

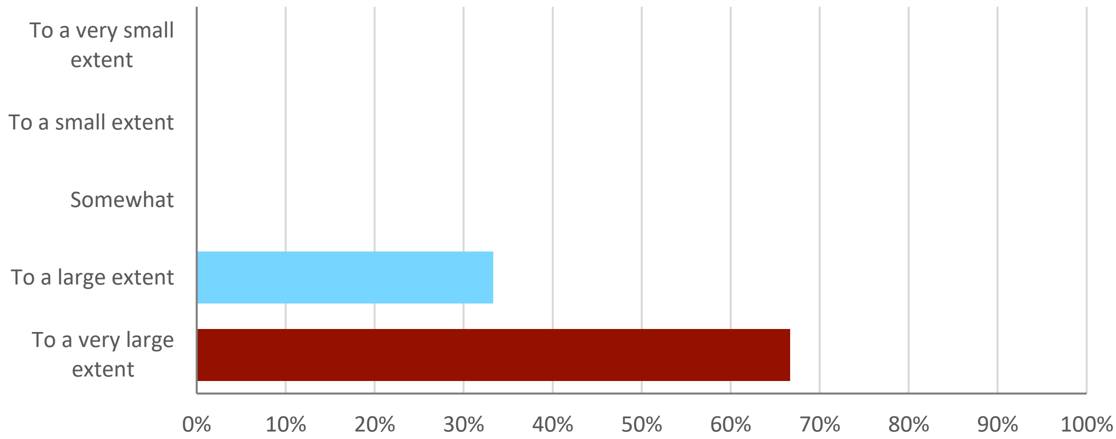
Question 17:



How is your company planning to fund growth over the next few years?

All respondents selected 'joint venture' as a means of funding growth for their respective companies over the coming years. A further 75 percent of respondents selected 'cash reserves' and 'cash flow finance', while another 50 percent of respondents selected 'equity', 'trade finance', and 'debt'. Only 25 percent of respondents selected 'asset finance' to fund future growth of their respective companies.

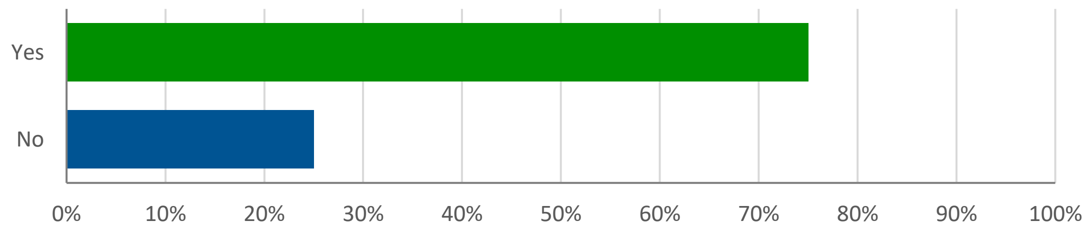
Question 18:



To what extent does market demand affect the supply of innovation?

Based on the responses, the majority of respondents indicated market demand affect the supply of innovation ‘to a very large extent’, while the remainder 33 percent of respondents indicated it affect ‘to a large extent’.

Question 19:



Does market demand for a particular technology influence your company’s decision to enter the market?

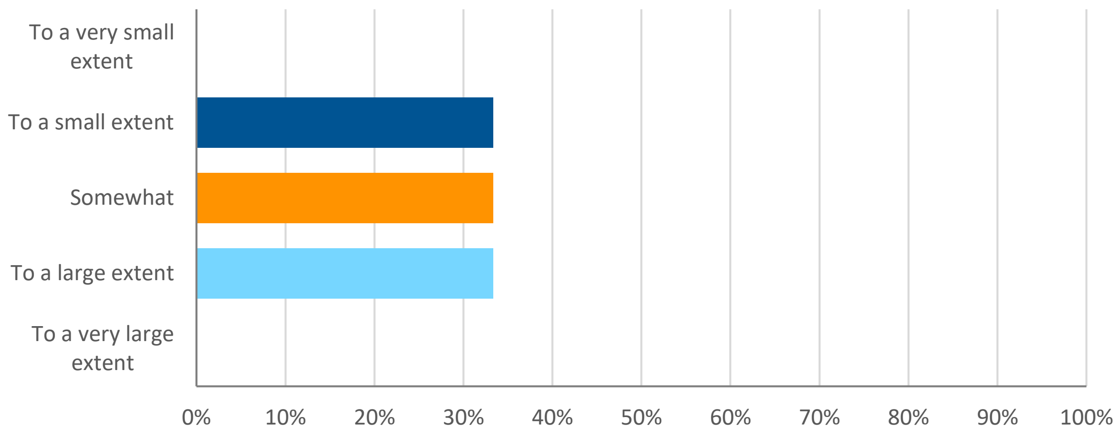
75 percent of respondents indicated market demand for a particular technology influenced their decision to enter the market, while the remainder 25 percent of respondents indicated they were not influenced by market demands. One of the respondents who was not influenced by market demands, said their reason for entering the market was due to the IMO regulations.

Question 20:

The reason identified from the responses on why companies were influenced to enter the market based on demands, was because of the opportunity it presented to them. It provided these companies with an opportunity to start a new venture to meet the demand, which may result in increased revenue.

One respondent further said that having a technology, or the knowledge to innovate based on that technology, was meaningless to any company. This is because companies do not benefit from developing a product based on the technology, if there were no demand for such a product from the market. According to the respondent, the product would just end up "*sitting on a shelf*" and not bring in any revenues for the company.

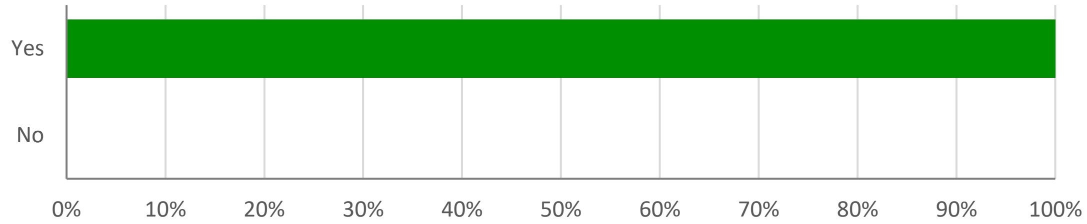
Question 21:



To what extent do you think social environment has an impact on encouraging innovation?

When respondents were asked to indicate to what extent they felt social environment encourages innovation, their responses were divided: 33 percent of respondents indicated 'to a small extent', 'somewhat' and 'to a large extent' respectively. Therefore, it is not sufficient to determine from the results whether social environment is considered as a factor that has any influences on encouraging innovation in manufacturing companies.

<u>Question 22:</u>

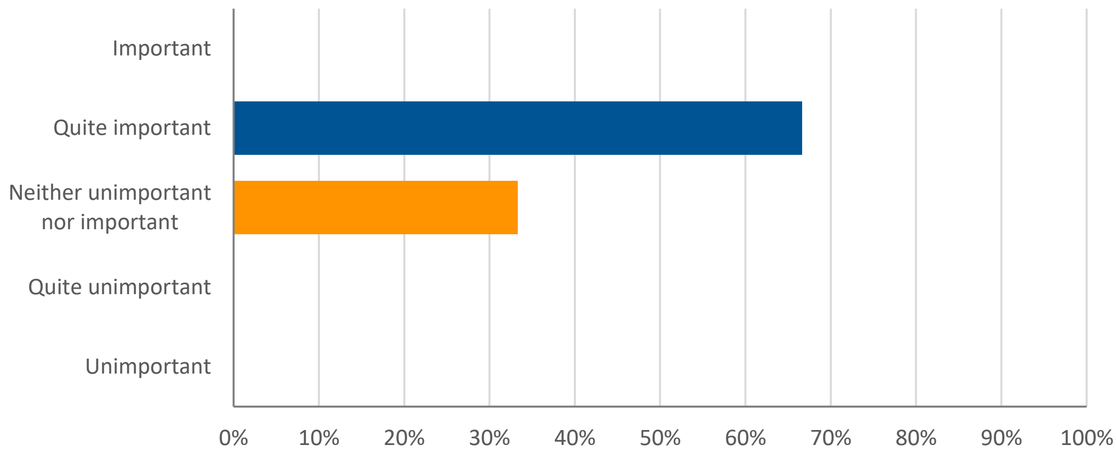


Does social environment affect innovation activities within your company?

All respondents agreed social environment affect innovation activities within their respective companies. According to one of the respondents, current social environment has encouraged their company to invest and develop in clean air technologies.

Another respondent, whose company had dedicated the past 60 years reducing all types of air pollutions, said their company *"believes in helping the environment"* through their products. In doing so, the respondent said their company can contribute to future generations having better quality of living. Hence, social environment is a factor that encouraged their company to innovate.

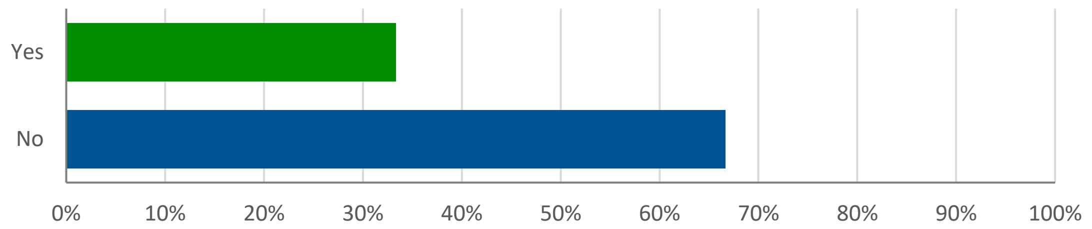
<u>Question 23:</u>



How important are social environmental factors on encouraging innovations within your company?

The majority of respondents indicated social environmental factors were 'quite important' in encouraging innovations within their respective companies. Based on the responses, it is evident that social environment is one of the drivers of innovation.

Question 24:

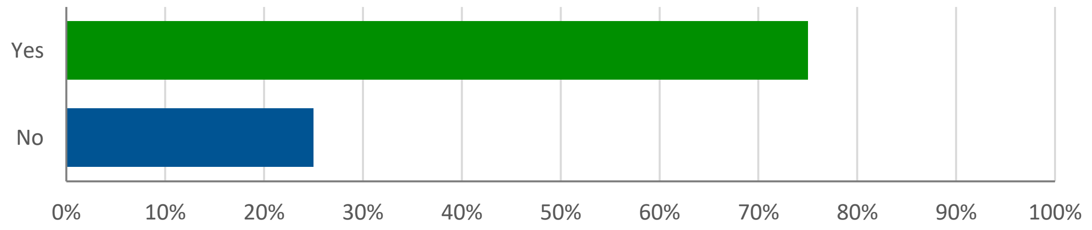


Does your company's CSR influence the level of innovation within your company?

67 percent of respondents indicated innovation activities within their respective companies were not influenced by their corporate social responsibility (CSR).

Only 33 percent of respondents indicated CSR influenced innovation within their respective companies. According to one of the respondents, this is because CSR is the general driver of product innovation for their company.

Question 25:

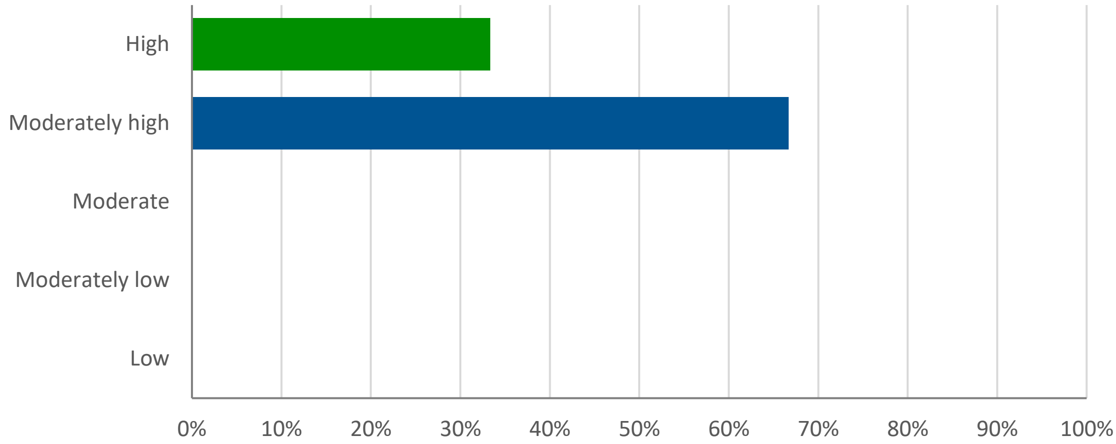


Do you consider your company to be a first-mover within your market segment?

75 percent of respondents considered their respective companies to be the first-mover for a product within their market segment. In other words, the majority of

respondents considers their product to be the first of its kind to be introduced in the market.

Question 26:



How much risk does your company accept when introducing new innovation?

Out of the 75 percent of respondents who considered their respective companies to be first-movers (Question 25), 67 percent of them indicated their respective companies were willing to accept 'moderately high' amounts of risk when introducing new innovations. The rest of the respondents however, were willing to take on much higher risks.